U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB80-123037

Shawnee Lime/Limestone Scrubbing Computerized Design/Cost-Estimate Model Users Manual

Tennessee Valley Authority, Muscle Shoals, AL

Prepared for

Industrial Environmental Research Lab, Research Triangle Park, NC

Aug 79

PB80-123037

EPA
TVA

United States Environmental Protection Agency | Industrial Environmental Research Laboratory, Research Triangle Park NC 27711 | EPA-600/7-79-210 August 1979

Tennessee Valley Authority, Office of Power | Emission Control Development Projects, Muscle Shoals AL 35660 | ECDP B-3

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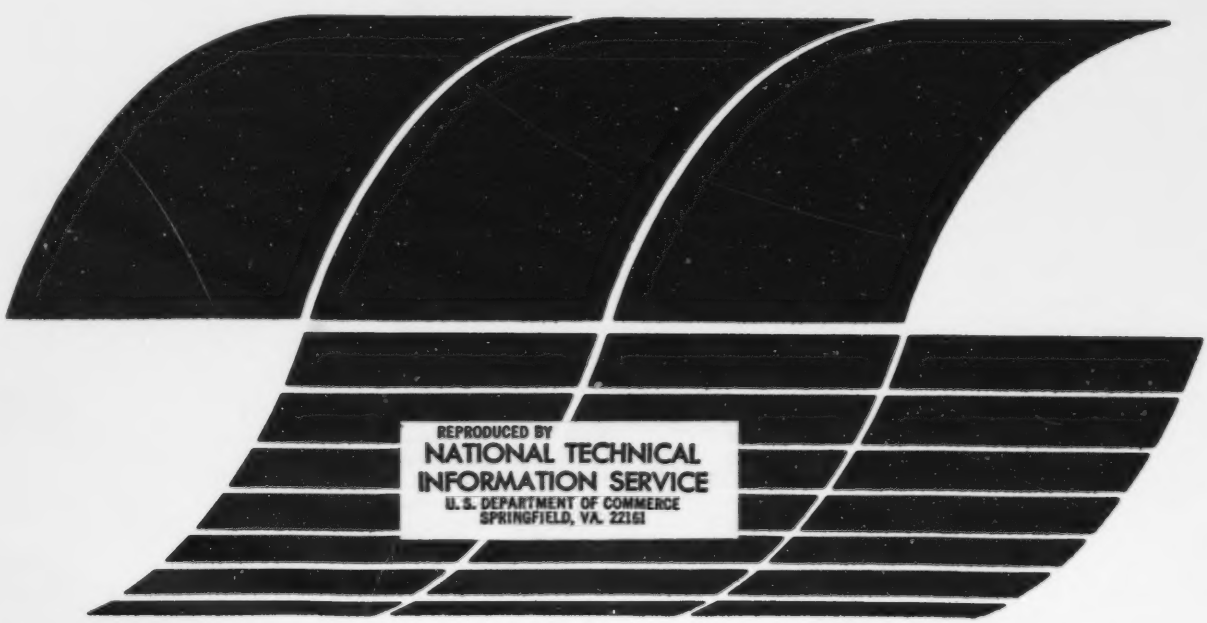
Interagency Energy/Environment R&D Program Report



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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/7-79-210		PB 80 123037

4. TITLE AND SUBTITLE	5. REPORT DATE
Shawnee Lime/Limestone Scrubbing Computerized Design/Cost-estimate Model Users Manual	August 1979
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
C. D. Stephenson and R. L. Torstrick	ECDP B-3
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
TVA, Office of Power Emission Control Development Projects Muscle Shoals, Alabama 35660	INE624A
	11. CONTRACT/GRANT NO. EPA Interagency Agreement D8-E721-BL
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711	Users Manual; 1/75 - 3/79
	14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES IERL-RTP project officer is John E. Williams, Mail Drop 61, 919/541-2483.

16. ABSTRACT The manual gives a general description of the Shawnee lime/limestone scrubbing computerized design/cost-estimate model and detailed procedures for using it. It describes all inputs and outputs, along with available options. The model, based on Shawnee Test Facility scrubbing data, includes a combination of material balance models provided to TVA by Bechtel National, Inc., and capital-investment/revenue requirement models developed by TVA. The model provides an estimate of total capital investment, first year operating revenue requirements, and lifetime revenue requirements for a lime or limestone scrubbing facility. Also included are a material balance, an equipment list, and a breakdown of costs by processing areas. The model should be used to project comparative economics of lime or limestone flue gas desulfurization processes (on the same basis as the model) or to evaluate system alternatives before developing a detailed design. The model is not intended for use in projecting the final system design.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Design	Pollution Control	13B	14B
Scrubbers	Cost Estimates	Stationary Sources	07A, 13I	14A
Sulfur Oxides	Desulfurization	Material Balances	07B	07D
Calcium Oxides				
Calcium Carbonates				
Mathematical Models			12A	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to Public	Unclassified	98
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE PC A05 MF A01

EPA Form 2220-1 (9-73)

EPA-600/7-79-210
ECDP B-3
August 1979

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EPA-IAG-D8-E721-BL

Program Element No. INE624A

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Research Triangle Park, NC 27711

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, DC 20460

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ABSTRACT

This manual provides a general description of the Shawnee lime-limestone scrubbing computerized design - cost-estimate model and the detailed procedures for using it. All inputs and outputs are described along with the options available. The model is based on Shawnee Test Facility scrubbing data and includes a combination of material balance models provided to the Tennessee Valley Authority (TVA) by Bechtel National, Incorporated, and capital investment - revenue requirement models developed by TVA. The model provides an estimate of total capital investment, first year operating revenue requirements, and lifetime revenue requirements for a lime or limestone scrubbing facility. Also provided are a material balance, equipment list, and a breakdown of costs by processing areas. The primary uses of the model should be for projecting comparative economics of lime or limestone flue gas desulfurization processes (on the same basis as the model) or in the evaluation of system alternatives prior to the development of a detailed design. The model is not intended for use in projecting the final design of a system.

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INTRODUCTION

Since 1968 the U.S. Environmental Protection Agency (EPA) has conducted a flue gas desulfurization (FGD) test facility at the Tennessee Valley Authority (TVA) coal-fired Shawnee Steam Plant near Paducah, Kentucky. TVA is the constructor and operator and Bechtel National, Incorporated, is the major contractor. The test facility originally consisted of three prototype-size scrubber units, each capable of processing about 30,000 aft^3/min (10 MW equivalent) of flue gas. One unit, a marble-bed absorber, was shut down in 1973 and converted to a cocurrent scrubber in 1978. The other two units, a mobile-bed absorber and a venturi spray tower, have been operated under a variety of conditions since 1972.

Bechtel and TVA have jointly developed a computer model capable of projecting comparative capital investment and annual lifetime revenue requirements for lime and limestone FGD scrubbing systems based on the Shawnee results. The model provides a simplified, consistent method for obtaining comparative projections on a common design and cost basis. It is not the primary purpose of the model to calculate the economics of an individual system to a high degree of accuracy, but there is sufficient detail to allow projections of preliminary conceptual design and costs for various lime or limestone scrubbing case variations. The model permits the estimation of the relative economics of these systems for variations in process design alternatives (such as limestone versus lime scrubbing, or alternative sludge disposal methods) or variations in the values of independent design criteria [such as scrubber gas velocity, liquid to gas (L/G) ratio, alkali stoichiometry, slurry residence time, reheat temperature, and sludge disposal method].

The development of the Shawnee computer economics model began in 1975, with the responsibility shared by Bechtel and TVA. Bechtel's major responsibility was developing models for calculating the overall material balance flow rates and stream compositions. TVA was responsible for determining the sizes of the required equipment, accumulating cost data for the major equipment items, and developing both a model for calculating equipment costs versus capacities and a model for projecting overall capital investment costs. TVA then developed procedures to use the output of these models in an existing TVA model that projects annual and lifetime revenue requirements.

The model should be useful to utility companies as well as architectural and engineering contractors who are involved in the selection and design of FGD facilities. It is intended to assist in the evaluation of system alternatives leading to the development of a detailed design rather than to project a final detailed design. It should also be useful for evaluating the potential effects of various process variables on economics as a guide for planning research and development activities. Although the model has

not been validated for comparing projected lime or limestone scrubber economics with the economics of alternate processes, these comparisons should be valid if the assumptions for the alternate systems are equivalent to the model assumptions for lime or limestone systems.

The model has already been used for several applications other than those for which it was specifically developed. Some examples are simulated industrial and utility boiler FGD applications, smelter FGD applications, partial scrubbing applications, plant fuel optimization studies, and comparison of coal-cleaning economics with total scrubbing. Probably the most important use to date has been support work for both EPA and the National Economic Research Associates assessment of nationwide effect of new-source performance standards (NSPS) revisions on the electric utility industry.

This manual provides the information and defines the procedures necessary to use the Shawnee lime and limestone computer model. It does not provide the concepts and background information basic to the model development. Presentations related to the model have been given at EPA industry briefings (1, 2) and an FGD symposium (3). The publications associated with these presentations discuss the model in general, describe the process and program options, and show sample results. Copies of these publications should be used in conjunction with the manual. Process flowsheets and diagrams are included in Appendix A to provide the user with the assumed equipment layout.

GENERAL INFORMATION

CURRENT SCOPE

The present model projects a complete conceptual design package for either a lime or limestone scrubbing system. It is designed for a wide range of options that are applicable to new coal-fired power units. Currently a mobile-bed (TCA) scrubber is assumed and four separate sludge disposal options are provided. Equipment size and layout configurations are based on units that range in size from 100 to 1300 MW and for coal sulfur contents that range from 2% to 5%. Because extreme variations in equipment sizes and layout configurations can result from factors other than unit size and coal sulfur content, ranges for some of these variables have been defined as follows:

Scrubber gas velocity	8-12.5 ft/sec
Liquor recirculation rate	25-75 gal/kft^3
Slurry residence time in hold tank	2-25 minutes
Number of scrubbing trains	1-10
SO_2 concentration	1500-4000 ppm

The validity of results for operating conditions outside the ranges shown above has not been determined. However, results for intermediate-sized plants operating outside these boundaries may still be valid in some cases.

Several model runs may be required to fully analyze the combined effects of individual input factors, especially if the specified ranges are exceeded. The effect of variations in inputs (such as scrubber gas velocity, degree of SO_2 removal, reheat temperature, alkali stoichiometry, or L/G ratio) on process design and economics can be determined individually by varying only one factor per model run, or the cumulative effect can be determined by varying several factors simultaneously.

FUTURE DEVELOPMENT

Further modifications to the model are expected to be made as test data from Shawnee become available. Bechtel and TVA are incorporating the results of the venturi spray tower tests at Shawnee into a design and cost model for that option. Other options which are being considered for incorporation as

sufficient data become available include (1) series scrubbers/high-alkali utilization systems, (2) forced-oxidation systems, (3) alternate scrubber configuration systems, and (4) systems with scrubber-loop additives such as magnesium oxide or adipic acid.

AVAILABILITY

The model is available to the public through TVA. Upon receipt of a written request, TVA provides a copy of the model suitable for loading onto an online computer system, along with FORTRAN program listings and the documentation required to execute the model.

TVA is presently loading the Shawnee Computer Model on the Control Data Corporation (CDC) CYBERNET system which is a nationwide, commercial data processing network. When this is complete, the program can be made available to the public after the appropriate authorization for use is cleared by TVA and billing arrangements are made between the user and CDC. Updated versions of the program will be maintained on this system and made available in the same manner as described above. Inputs are subject to change as the model is expanded.

Requests for copies of the computer model or additional information should be made to the authors at the following address: Emission Control Development Projects, Tennessee Valley Authority, Muscle Shoals, Alabama 35660, telephone number (205) 383-4631, extension 2516.

MODEL DESCRIPTION

INPUT

The overall model requires a minimum of 14 lines of input. Additional input is required when a variable operating profile is chosen instead of the built-in profiles. A detailed FORTRAN variable list of the model input is shown in Table B-1 of Appendix B. The variables are defined in Table B-2 of Appendix B. Ranges for key variables to aid in establishing input data to the model are shown in Table 1.

As new options are incorporated, the required inputs are subject to change. When this occurs, the list of variables and the associated definitions will be updated and made available as necessary.

OUTPUT

The outputs of the Shawnee lime-limestone computer model provide a complete conceptual design package for lime or limestone scrubbing, consisting of (1) a detailed material balance including properties of the major streams; (2) a detailed water balance itemizing water availability and water required; (3) specifications of the scrubber system design; (4) a display of overall pond design and costs; (5) specifications and costs of the process equipment by major processing area; (6) a detailed breakdown of the projected capital investment requirements; (7) an itemized breakdown of the projected revenue requirements by component for the first year of operation of the system; (8) a lifetime revenue requirement analysis showing projected costs for each year of operation of the plant as well as lifetime cumulative and discounted costs and equivalent unit revenue requirements; and (9) a particulate removal cost table which lists operating conditions and itemizes installed and operating costs for a cold electrostatic precipitator (ESP), a hot ESP, a baghouse, and a wet scrubber. The output for the upstream particulate removal options has not yet been integrated into the lifetime economic projections. These outputs are illustrated in the base case printout shown in Appendix C.

OPTIONS

A detailed list of all of the model inputs is included in Tables B-1 and B-2 of Appendix B. These tables include a number of options for selecting process design and controlling model output. These options are listed below:

TABLE 1. VARIABLE RANGES

Item	Description
Power plant	New, 100-1300 MW
Fuel sulfur content	2-5%
Scrubber gas velocity	8-12.5 ft/sec
Liquor recirculation rate	25-75 gal/kft^3
Effluent hold tank residence time	2-25 minutes
Number of scrubbing trains	1-10
Number of spare scrubbing trains	0-10
Sulfur to overhead as SO_2 gas	0-100%
Ash to overhead as fly ash	0-100%
System pressure drop	Should not exceed 3 inches per TCA stage
Investment year	Midpoint of project expenditure schedule
Revenue requirement year	First year of operation of plant

Note: The variable ranges were established for model development purposes. Values beyond these ranges are not necessarily invalid but the margin for error is potentially greater when these ranges are exceeded.

- Print options
- Particulate collection device options
- Particulate removal specification options
- SO_2 removal specification options
- Operating parameter calculation options
- Lime or limestone scrubbing option
- Redundancy options
- Sludge disposal options
- Pond design options
- Pond liner options
- Pond capacity option
- Operating profile options

Some examples of the various options are shown on the pages that follow. For illustration purposes the appropriate data line is shown and the particular option code is indicated. An explanation of each option and sample output resulting from its usage is provided where necessary. Values for all variables must be entered for each case even though a variable value is being calculated by the model as a result of a user-specified option. When this condition occurs, the calculated value will override the input value. A value of zero will be appropriate for many variables but the value cannot be omitted. Spaces cannot be used to take the place of variables which have a value equal to zero.

Some user-specified input values result in the use of default values of other variables for consistency in the calculations. For the options that allow defaults, the option code that must be input and the default values that are assumed are described.

Print Options

Line No.	Input Data
1	1, 1, 1, 1, 1
2	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
3	1, 1, 1

The options on the first three lines of the input data control printed output from the model. These options are described in the input definition list in Appendix B, Table B-2. The only print option requiring further explanation is the first option on line 3. This option controls the printout of the investment and revenue requirement sections. The short form printout is shown in Table 2 and may be compared with the long printout of the base case example in Appendix C.

TABLE 2. SAMPLE SHORT-FORM PRINTOUT

LIMESTONE SLURRY PROCESS -- BASIS: 500 MW UNIT, 1980 STARTUP

BASE CASE EXAMPLE 500 MW CASE 002

PROJECTED CAPITAL INVESTMENT REQUIREMENTS

	INVESTMENT, THOUSANDS OF 1979 DOLLARS			
	RAW MATERIAL HANDLING AND PREPARATION	SCRUBBING	WASTE DISPOSAL	TOTAL
SUBTOTAL DIRECT INVESTMENT	3969.	19725.	7826.	31520.
TOTAL CAPITAL INVESTMENT	6826.	33884.	14664.	55374.

(continued)

TABLE 2 (continued)

PROJECTED FIRST YEAR REVENUE REQUIREMENTS

ANNUAL OPERATION KW-HR/KW = 4512	REVENUE REQUIREMENT, $
SUBTOTAL RAW MATERIAL	885400
SUBTOTAL CONVERSION COSTS	3893400
SUBTOTAL INDIRECT COSTS	12965300
TOTAL FIRST YEAR REVENUE REQUIREMENT	17744100

PROJECTED LIFETIME REVENUE REQUIREMENTS

LIFETIME TOTAL REVENUE REQUIREMENT, DOLLARS	4107348000
LIFETIME AVERAGE INCREASE IN UNIT REVENUE REQUIREMENT	
DOLLARS PER TON OF COAL BURNED	13.13
MILLS PER KILOWATT-HOUR	5.63
CENTS PER MILLION BTU HEAT INPUT	62.52
DOLLARS PER TON OF SULFUR REMOVED	521.44
REVENUE REQUIREMENT DISCOUNTED AT 11.6% TO INITIAL YEAR, DOLLARS	132942000
LEVELIZED INCREASE IN UNIT REVENUE REQUIREMENT EQUIVALENT TO DISCOUNTED REQUIREMENT OVER LIFE OF POWER UNIT	
DOLLARS PER TON OF COAL BURNED	14.80
MILLS PER KILOWATT-HOUR	6.34
CENTS PER MILLION BTU HEAT INPUT	70.47
DOLLARS PER TON OF SULFUR REMOVED	587.98

Particulate Collection Device Options

Line No.	Input Data
5	2, 500, 9000, 10500, 33, 300, 2, 175, 470, 751

XESP

The particulate collection device (4) option is controlled by the XESP code. The value of XESP may be 0, 1, or 2. A zero value is used if a particulate removal device is not desired. A value of 1 is used if a mechanical collector (33% efficient) is selected. If option 1 is chosen, the code for upstream removal (ASHUPS, see Table B-2) should have an input value of 33 (% removal). If an XESP value of 2 is selected, a separate particulate removal cost model projects the investment and operating costs for particulate removal and the results are listed after the investment printout. The percentage particulate removal required for this option is specified by the ASHUPS variable. The investment and revenue requirements for the particulate removal device are printed separately. They are not included with the first year and lifetime FGD costs.

Sample outputs corresponding to XESP values are as follows:

XESP = 0 No illustration required

XESP = 1 Table 3 shows a printout of equipment lists itemized for mechanical collector costs

XESP = 2 Refer to the printout shown in the base case example in Appendix C

Particulate Removal Options

Line No.	Input Data
6	57.56 4.14 7.00 1.29 3.12 .1 16.0 10.74 95 80 1 98.5 50

IASH ASHUPS ASHSCR

The particulate removal variables are IASH, ASHUPS, and ASHSCR. The IASH option identifies the method for specifying particulate removal, i.e., as percent removal or as outlet emission in lb/MBtu. IASH may take values of 0, 1, 2, or 3. If IASH is equal to 0, upstream particulate removal (ASHUPS) and scrubber particulate removal (ASHSCR) take default values of 33% and 99.2% removal respectively. If IASH equals 1, ASHUPS and ASHSCR are input as percent removal. If IASH equals 2, ASHUPS and ASHSCR are input particulate loadings in lb/MBtu at the outlet of the upstream particulate collector and the scrubber respectively. If IASH equals 3, ASHUPS is input as percent removal and ASHSCR takes a default value of 75%. Regardless of the option chosen, the output listing provides the equivalent particulate emission from

TABLE 3. MECHANICAL COLLECTOR COST ILLUSTRATION

SCRUBBING

INCLUDING 4 OPERATING AND 1 SPARE SCRUBBING TRAINS

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
MECHANICAL ASH COLLECTOR	33% PARTICULATE REMOVAL	1	424515.	78325.
F.D. FANS	20.0IN H2O, WITH 1615. HP MOTOR AND DRIVE	5	1873839.	113586.
SHELL			812283.	
RUBBER LINING			1199962.	
MIST ELIMINATOR			368717.	
SLURRY HEADER AND NOZZLES			313679.	
GRIDS			471794.	
SPHERES			175683.	
TOTAL TCA SCRUBBER COSTS		5	3342115.	278548.
REHEATERS		5	1046932.	43280.
SOOTBLOWERS		60	404468.	298505.
EFFLUENT HOLD TANK	231287.GAL, 34.0FT DIA, 34.0FT HT, FLAKEGLASS-LINED CS	5	181225.	354208.
EFFLUENT HOLD TANK AGITATOR	63.HP	5	345851.	127622.
COOLING SPRAY PUMPS	1274.GPM 100FT HEAD, 59.HP, 4 OPERATING AND 6 SPARE	10	117520.	17352.
ABSORBER RECYCLE PUMPS	8761.GPM, 100FT HEAD, 406.HP, 8 OPERATING AND 7 SPARE	15	658657.	51730.
MAKEUP WATER PUMPS	2549.GPM, 200.FT HEAD, 215.HP, 1 OPERATING AND 1 SPARE	2	19790.	1826.
TOTAL EQUIPMENT COST			8414911.	1364980.

the upstream ash collector and the TCA scrubber as both percent removal and lb/MBtu. Sample output for an IASH option equal to 1 is shown in Appendix C; printouts for the other options are very similar. A summary of the options is shown below.

IASH = 0 ASHUPS default value = 33% removal
ASHSCR default value = 99.2% removal

IASH = 1 ASHUPS input value as percent removal
ASHSCR input value as percent removal
(Appendix C shows sample printout using IASH = 1)

IASH = 2 ASHUPS input value as lb/MBtu to scrubber
ASHSCR input value as lb/MBtu from scrubber

IASH = 3 ASHUPS input value as percent removal
ASHSCR default value equals 75% removal

SO_2 Removal Options

Line No.	Input Data
7	55 0 0 12.5 25 1 85 12 1 0.0 1 0 0 2.85 5 0 0

ISO2 XSO2

The model has four methods for specifying SO_2 outlet concentrations or removal. The controlling variables are the ISO2 option and the actual value to be removed, XSO2. If ISO2 = 1, XSO2 is input as percent SO_2 removed. If ISO2 = 2, XSO2 is input as the scrubber outlet emission expressed as pounds SO_2/MBtu. If ISO2 = 3, XSO2 is input as ppm SO_2 in the scrubber outlet stream. A fourth method for specifying SO_2 removal (SO_2 removal calculated) is described in the operating parameter options section. Sample output for ISO2 option 1 is shown in Appendix C. Regardless of the option chosen, the equivalent SO_2 removal in all three units is displayed. The input value is indicated as having been specified and the other values are indicated as having been calculated. A summary of the input options is shown below.

ISO2 = 1 XSO2 is input as percent removal

ISO2 = 2 XSO2 is input as pounds SO_2/MBtu at the scrubber outlet

ISO2 = 3 XSO2 is input as ppm SO_2 in the scrubber outlet stream

The SO_2 removal options are long-term average removals and are not to be construed as 3-hour or 24-hour averages. At this point an important design consideration should be emphasized. When sizing an FGD facility the raw material handling, feed preparation, and scrubbing areas should be based on the maximum sulfur content of the coal rather than the long-term average. The waste disposal pond, however, should be sized on the long-term average sulfur content. The user may accomplish this by inputting the weight percent

sulfur as the maximum expected and then entering the pond capacity factor (discussed later) to adjust the total amount of sludge generated back to the equivalent long-term average amount.

Operating Parameter Calculation Option

Line No.	Input Data
	XLG ↑ XSO2 ↑ XSR ↑ SRIN ↑
7	55 0 0 12.5 25 1 85 12 1 0.0 1 0 0 2.85 5 0 0
8	15 40 .2 40 30 65 1.2 7.0 0 12 20 ↓ PHLIME

Four options are available in the model to allow either user input or model calculation of the major operating parameters which include L/G (expressed as scrubber liquor recirculation rate in gallons of liquor recirculated per 1000 actual cubic feet of gas at the scrubber outlet), stoichiometry (expressed as moles $CaCO_3$ or CaO added per mole of SO_2 absorbed), and SO_2 removal. The options differ slightly for the limestone scrubbing system and the lime scrubbing system described below; therefore the description is divided into two sections. First, for limestone scrubbing (XIALK = 1) the variables are XSR, XLG, SRIN, and XSO2. XSR is the controlling option and takes values from 0 to 3. If XSR has an input value of 0, the L/G (XLG), stoichiometry (SRIN), and SO_2 removal (XSO2) are all user input values. If XSR is equal to 1, XLG and XSO2 are input and the model calculates stoichiometry. When XSR is equal to 2, SRIN and XSO2 are input and the model calculates XLG. If XSR is equal to 3, both XLG and SRIN are input and the model calculates XSO2. A summary of the various options for a limestone scrubbing system is shown below.

XSR = 0 XLG is input
SRIN is input
XSO2 is input

XSR = 1 XLG is input
SRIN is calculated
XSO2 is input
(XSR = 1 is shown in the base case printout in Appendix C)

XSR = 2 XLG is calculated
SRIN is input
XSO2 is input

XSR = 3 XLG is input
SRIN is input
XSO2 is calculated

Similar options are available in the lime scrubbing option (XIALK = 2) except that the variable PHLIME replaces SRIN. The model does not calculate the lime stoichiometry but does calculate the pH of the recirculation liquor. Values for SRIN and PHLIME must be entered even when values for these variables are being calculated within the program (zero is typically input if this is the case). When inputting SRIN, values of 1.01 or greater should be used. A summary of the options for a lime scrubbing system is shown below.

XSR = 0 XLG is input
PHLIME is input
XSO2 is input

XSR = 1 XLG is input
XSO2 is input
PHLIME is calculated

XSR = 2 PHLIME is input
XSO2 is input
XLG is calculated

XSR = 3 XLG is input
SRIN is input
XSO2 is calculated

The output listing for the lime scrubbing option is similar to that for the limestone option except that the stoichiometry is printed out for CaO instead of $CaCO_3$, as shown in Table 4.

Lime or Limestone Scrubbing Option

Line No.	Input Data
7	55 0 0 12.5 25 1 85 12 1 0.0 1 0 0 2.85 5 0 0

XIALK

The model allows the choice of either lime or limestone absorbent. The input variable controlling this option is XIALK. If XIALK = 1, limestone slurry is selected as the scrubbing medium. If XIALK = 2, lime slurry is selected. The base case printout in Appendix C shows an example of the limestone scrubbing option. Table 5 shows how the lime option output differs from limestone in both the input display and the raw material preparation area equipment list.

TABLE 4. LIME SCRUBBING OUTPUT LISTING

SCRUBBER SYSTEM

TOTAL NUMBER OF SCRUBBING TRAINS (OPERATING+REDUNDANT) = 5

SO2 REMOVAL = 85.0 PERCENT

PARTICULATE REMOVAL IN SCRUBBER SYSTEM = 50.0 PERCENT

TCA PRESSURE DROP ACROSS 3 BEDS = 8.6 IN. H2O

TOTAL SYSTEM PRESSURE DROP = 14.8 IN. H2O

OVERRIDE TOTAL SYSTEM PRESSURE DROP = 20.0 IN. H2O

SPECIFIED LIQUID-TO-GAS-RATIO = 55. GAL/1000 ACF

LIME ADDITION = 0.2139E+05 LB/HR DRY LIME

CALCULATED LIME STOICHIOMETRY = 1.10 MOLE CAO ADDED AS LIME PER MOLE SO2 ABSORBED

SOLUBLE CAO FROM FLY ASH = 0.0 MOLE PER MOLE SO2 ABSORBED

TOTAL SOLUBLE MGO = 0.0 MOLE PER MOLE SO2 ABSORBED

TOTAL STOICHIOMETRY = 1.10 MOLE SOLUBLE (CA+MG) PER MOLE SO2 ABSORBED

SCRUBBER INLET LIQUOR PH = 6.99

MAKE UP WATER = 579. GPM

CROSS-SECTIONAL AREA PER SCRUBBER = 424. SQ FT

SYSTEM SLUDGE DISCHARGE

SPECIES	LB-MOLE/HR	LB/HR	SOLID COMP, WT %	LIQUID COMP, PPM
CASO3 ,1/2 H2O	0.2356E+03	0.3042E+05	59.13	
CASO4 ,2H2O	0.1002E+03	0.1724E+05	33.51	
CACO3	0.2763E+02	0.2766E+04	5.38	
INSOLUBLES	----------	0.1021E+04	1.98	
H2O	0.4239E+04	0.7637E+05		
CA++	0.6972E+01	0.2794E+03		3621.
MG++	0.0	0.0		0.
SO3--	0.1248E+00	0.9993E+01		129.
SO4--	0.8573E+00	0.8235E+02		1067.
CL-	0.1198E+02	0.4245E+03		5501.

TOTAL DISCHARGE FLOW RATE = 0.1286E+06 LB/HR
= 194. GPM

TOTAL DISSOLVED SOLIDS IN DISCHARGE LIQUID = 10319. PPM

DISCHARGE LIQUID PH = 7.29

TABLE 5. LIME OPTION INPUTS

BASE CASE EXAMPLE 500 MW CASE 004

*** INPUTS ***

BOILER CHARACTERISTICS

MEGAWATTS = 500.

BOILER HEAT RATE = 9000. BTU/KWH

EXCESS AIR = 33. PERCENT, INCLUDING LEAKAGE

HOT GAS TEMPERATURE = 300. DEG F

COAL ANALYSIS, WT % AS FIRED :

C	H	O	N	S	CL	ASH	H2O
57.56	4.14	7.00	1.29	3.12	0.10	16.00	10.74

SULFUR OVERHEAD = 95.0 PERCENT

ASH OVERHEAD = 80.0 PERCENT

HEATING VALUE OF COAL = 10500. BTU/LB

FLYASH REMOVAL	EFFICIENCY, %	EMISSION, LBS/M BTU
UPSTREAM OF SCRUBBER	98.5	0.18
WITHIN SCRUBBER	50.0	0.09

ALKALI

LIME :

CAO = 97.15 WT % DRY BASIS
SOLUBLE MGO = 0.0
INERTS = 2.85
MOISTURE CONTENT : 5.00 LB H2O/100 LBS DRY LIME

FLY ASH :

SOLUBLE CAO = 0.0 WT %
SOLUBLE MGO = 0.0
INERTS = 100.00

RAW MATERIAL HANDLING AREA

NUMBER OF REDUNDANT ALKALI PREPARATION UNITS = 1

(continued)

TABLE 5 (continued)

RAW MATERIAL HANDLING AND PREPARATION

INCLUDING 2 OPERATING AND 1 SPARE PREPARATION UNITS

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
CONVEYOR FROM CALCINATION PLANT	1500FT HORIZONTAL, 30HP	1	153293.	46144.
STORAGE SILO ELEVATOR	123.FT HIGH, 50 HP	1	104830.	2128.
CONCRETE STORAGE SILO	128311.FT3,47.8FT DIA , 71.6FT STRAIGHT SIDE STORAGE HT	1	72886.	174769.
STORAGE SILO HOPPER BOTTOM	60 DEGREE, CS	1	11292.	33619.
RECLAIM VIBRATING FEEDER	3.5HP	1	12134.	1866.
RECLAIM BELT CONVEYOR	123.FT HORIZONTAL, 5HP	1	17279.	4236.
FEED BIN ELEVATOR	50FT HIGH, 50HP	1	49615.	995.
FEED BELT CONVEYOR	50FT HORIZONTAL, 5HP	1	12943.	2114.
FEED CONVEYOR TRIPPER	30FPM, 1HP	1	13482.	2488.
FEED BIN	10FT DIA, 15FT STRAIGHT SIDE HT, COVERED, CS	3	8089.	14925.
BIN VIBRATING FEEDER	3.5HP	3	13752.	4851.
BIN WEIGH FEEDER	12FT, 12IN SCREW, 1HP	3	17797.	1866.
SLAKER	5.TPH, 10.HP	3	169545.	15641.
SLAKER PRODUCT TANK		3	18201.	28358.
SLAKER PRODUCT TANK AGITATOR	10HP	3	21437.	1119.
LIME SYSTEM DUST COLLECTORS	POLYPROPYLENE BAG TYPE 2200 CFM,7.5HP	5	26290.	62189.
SLAKER PRODUCT TANK SLURRY PUMPS	125.GPM, 60FT HEAD, 4.HP, 2 OPERATING AND 1 SPARES	3	10865.	2279.
SLURRY FEED TANK	132390.GAL, 28.2FT DIA, 28.2FT HT, FLAKEGLASS-LINED CS	1	22023.	47199.
SLURRY FEED TANK AGITATOR	48.HP	1	47310.	3492.
SLURRY FEED TANK PUMPS	63.GPM, 60 FT HEAD, 2.HP, 4 OPERATING AND 4 SPARE	8	20654.	3980.
TOTAL EQUIPMENT COST			823718.	454255.

Redundancy Options

Line No.	Input Data
9	2 3 4 5 35 .0000001 30 10 1.35 1 4 1 .1

NSPREP NORTRAN NOREDN

Options for redundancy in the model apply to the raw material preparation area and the scrubbing area. The controlling input variables are NSPREP, NOTRAN, and NOREDN. NSPREP specifies the number of spare preparation units (ball mills or slakers) and may be given any value, 0, 1, 2, 3, ... NOTRAN specifies the number of operating scrubbers. A program override automatically changes the value of NOTRAN if the specified number requires a scrubber larger than the maximum available size. NOREDN indicates the number of spare scrubber trains. The base case equipment list in Appendix C shows the output for a limestone scrubbing system designed with redundancy in both ball mills and scrubbers. For comparison, Table 6 shows similar output for a lime system with redundancy in both the preparation area (slakers) and scrubber area.

Sludge Disposal Option

Line No.	Input Data
10	1 0 500 3500 25 25 5280 1 12 2.5

ISLUDG SDFEE

Four sludge disposal options are provided in the model. The input variables are ISLUDG and SDFEE. ISLUDG may take the values 1, 2, 3, or 4. SDFEE specifies the cost per dry ton to fix or treat the sludge. When ISLUDG = 1 the model assumes an onsite ponding sludge disposal system. If ISLUDG = 2 a disposal system consisting of a gravity thickener and an onsite pond is assumed. For ISLUDG = 3 the disposal system includes costs for a gravity thickener and fixation. Total fixation and disposal costs are input as $/ton of dry sludge to be fixed. Option 4 is similar to option 3 except that a rotary vacuum filter is added to the system downstream from the thickener prior to fixation. The fixation fee is applied in the same manner as for ISLUDG = 3; however, in this case the material being fixed is the filter cake. Ordinarily SDFEE will be zero for options 1 and 2 but an additional fee for fixation of the sludge in the pond can be included by setting SDFEE equal to the desired fee value. The base case printout in Appendix C is an example of the onsite ponding option. Sample output for the other sludge disposal options are shown in Tables 7-9. Year 1 and lifetime revenue requirements corresponding to sludge disposal option 4 are shown in Tables 10 and 11. A summary of the available sludge disposal options is given on page 27.

TABLE 6. LIME REDUNDANCY

SCRUBBER SYSTEM VARIABLES

NUMBER OF OPERATING SCRUBBING TRAINS = 4

NUMBER OF REDUNDANT SCRUBBING TRAINS = 1

NUMBER OF BEDS = 3

NUMBER OF GRIDS = 4

HEIGHT OF SPHERES PER BED = 5.0 INCHES

LIQUID-TO-GAS RATIO = 55. GAL/1000 ACF

SCRUBBER GAS VELOCITY = 12.5 FT/SEC

SO2 REMOVAL = 85. PERCENT

STOICHIOMETRY RATIO TO BE CALCULATED

ENTRAINMENT LEVEL = 0.10 WT %

EHT RESIDENCE TIME = 12.0 MIN

SO2 OXIDIZED IN SYSTEM = 30.0 PERCENT

SOLIDS IN RECIRCULATED SLURRY = 15.0 WT %

SOLIDS DISPOSAL SYSTEM

COST OF LAND = 3500.00 DOLLARS/ACRE

SOLIDS IN SYSTEM SLUDGE DISCHARGE = 40.0 WT %

MAXIMUM POND AREA = 500. ACRES

MAXIMUM EXCAVATION = 25.00 FT

DISTANCE TO POND = 5280. FT

POND LINED WITH 12.0 INCHES CLAY

STEAM REHEATER (IN-LINE)

SATURATED STEAM TEMPERATURE = 470. DEG F

HEAT OF VAPORIZATION OF STEAM = 751. BTU/LB

OUTLET FLUE GAS TEMPERATURE = 175. DEG F

SUPERFICIAL GAS VELOCITY (FACE VELOCITY) = 25.0 FT/SEC

(continued)

TABLE 6 (continued)

RAW MATERIAL HANDLING AND PREPARATION

INCLUDING 2 OPERATING AND 1 SPARE PREPARATION UNITS

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
CONVEYOR FROM CALCINATION PLANT	1500FT HORIZONTAL, 30HP	1	153293.	46144.
STORAGE SILO ELEVATOR	123.FT HIGH, 50 HP	1	104830.	2128.
CONCRETE STORAGE SILO	128311.FT3,47.8FT DIA , 71.6FT STRAIGHT SIDE STORAGE HT	1	72886.	174769.
STORAGE SILO HOPPER BOTTOM	60 DEGREE, CS	1	11292.	33619.
RECLAIM VIBRATING FEEDER	3.5HP	1	12134.	1866.
RECLAIM BELT CONVEYOR	123.FT HORIZONTAL, 5HP	1	17279.	4236.
FEED BIN ELEVATOR	50FT HIGH, 50HP	1	49615.	995.
FEED BELT CONVEYOR	50FT HORIZONTAL, 5HP	1	12943.	2114.
FEED CONVEYOR TRIPPER	30FPM, 1HP	1	13482.	2488.
FEED BIN	10FT DIA, 15FT STRAIGHT SIDE HT, COVERED, CS	3	8089.	14925.
BIN VIBRATING FEEDER	3.5HP	3	13752.	4851.
BIN WEIGH FEEDER	12FT, 12IN SCREW, 1HP	3	17797.	1866.
SLAKER	5.TPH, 10.HP	3	169545.	15641.
SLAKER PRODUCT TANK		3	18201.	28358.
SLAKER PRODUCT TANK AGITATOR	10HP	3	21437.	1119.
LIME SYSTEM DUST COLLECTORS	POLYPROPYLENE BAG TYPE 2200 CFM,7.5HP	5	26290.	62189.
SLAKER PRODUCT TANK SLURRY PUMPS	125.GPM, 60FT HEAD, 4.HP, 2 OPERATING AND 1 SPARES	3	10865.	2279.
SLURRY FEED TANK	132390.GAL, 28.2FT DIA, 28.2FT HT, FLAKEGLASS-LINED CS	1	22023.	47199.
SLURRY FEED TANK AGITATOR	48.HP	1	47310.	3492.
SLURRY FEED TANK PUMPS	63.GPM, 60 FT HEAD, 2.HP, 4 OPERATING AND 4 SPARE	8	20654.	3980.
TOTAL EQUIPMENT COST			823718.	454255.

(continued)

TABLE 6 (continued)

SCRUBBING

INCLUDING 4 OPERATING AND 1 SPARE SCRUBBING TRAINS

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
F.D. FANS	20.0IN H2O, WITH 1615. HP MOTOR AND DRIVE	5	1873839.	113586.
SHELL			810950.	
RUBBER LINING			1197826.	
MIST ELIMINATOR			367711.	
SLURRY HEADER AND NOZZLES			312705.	
GRIDS			470533.	
SPHERES			175220.	
TOTAL TCA SCRUBBER COSTS		5	3334943.	278051.
REHEATERS		5	1044633.	43199.
SOOTBLOWERS		60	404468.	298505.
EFFLUENT HOLD TANK	230676.GAL, 34.0FT DIA, 34.0FT HT, FLAKEGLASS-LINED CS	5	180907.	353585.
EFFLUENT HOLD TANK AGITATOR	63.HP	5	345122.	127353.
COOLING SPRAY PUMPS	1271.GPM 100FT HEAD, 59.HP, 4 OPERATING AND 6 SPARE	10	117460.	17336.
ABSORBER RECYCLE PUMPS	8738.GPM, 100FT HEAD, 405.HP, 8 OPERATING AND 7 SPARE	15	658180.	51682.
MAKEUP WATER PUMPS	2542.GPM, 200.FT HEAD, 214.HP, 1 OPERATING AND 1 SPARE	2	19759.	1823.
TOTAL EQUIPMENT COST			7979309.	1285116.

TABLE 7. EXAMPLE EQUIPMENT LIST FOR SLUDGE OPTION 2

WASTE DISPOSAL

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
ABSORBER BLEED RECEIVING TANK	57760.GAL, 17.0FT DIA, 34.0FT HT, FLAKGLASS-LINED CS	1	14579.	31228.
ABSORBER BLEED TANK AGITATOR	36.HP	1	20467.	1511.
POND FEED SLURRY PUMPS	237.GPM, 130.FT HEAD 9.HP, 2 OPERATING AND 2 SPARE	4	21577.	3810.
POND SUPERNATE PUMPS	561.GPM, 192.FT HEAD, 45.HP, 1 OPERATING AND 1 SPARE	2	8632.	796.
THICKENER FEED PUMP	760.GPM, 60FT HEAD, 21.HP, 1 OPERATING AND 1 SPARE	2	13266.	2887.
THICKENER	20872.SQ.FT.,163.FT DIA, 8.9FT HT	1	566700.	401870.
THICKENER OVERFLOW PUMPS	500.GPM, 75.0FT HEAD, 16.HP, 1 OPERATING AND 1 SPARE	2	6184.	570.
THICKENER OVERFLOW TANK	8256.GAL, 12.6FT DIA, 8.9FT HT	1	1788.	4288.
TOTAL EQUIPMENT COST			653193.	446961.

TABLE 8. EXAMPLE EQUIPMENT LIST FOR SLUDGE OPTION 3

WASTE DISPOSAL

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
ABSORBER BLEED RECEIVING TANK	57760.GAL, 17.0FT DIA, 34.0FT HT, FLAKGLASS-LINED CS	1	14579.	31228.
ABSORBER BLEED TANK AGITATOR	36.HP	1	20467.	1511.
THICKENER FEED PUMP	760.GPM, 60FT HEAD, 21.HP, 1 OPERATING AND 1 SPARE	2	13266.	2887.
THICKENER	20872.SQ.FT.,163.FT DIA, 8.9FT HT	1	566700.	401870.
THICKENER OVERFLOW PUMPS	500.GPM, 75.0FT HEAD, 16.HP, 1 OPERATING AND 1 SPARE	2	6184.	570.
THICKENER OVERFLOW TANK	8256.GAL, 12.6FT DIA, 8.9FT HT	1	1788.	4288.
SLUDGE FIXATION FEED PUMP	237.GPM, 50FT HEAD, 7.HP, 1 OPERATING AND 1 SPARE	2	10629.	1905.
TOTAL EQUIPMENT COST			633612.	444259.

TABLE 9. EXAMPLE EQUIPMENT LIST FOR SLUDGE OPTION 4

WASTE DISPOSAL

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
ABSORBER BLEED RECEIVING TANK	57760.GAL, 17.0FT DIA, 34.0FT HT, FLAKGLASS-LINED CS	1	14579.	31228.
ABSORBER BLEED TANK AGITATOR	36.HP	1	20467.	1511.
THICKENER FEED PUMP	745.GPM, 60FT HEAD, 21.HP, 1 OPERATING AND 1 SPARE	2	13236.	2866.
THICKENER	20448.SQ.FT.,161.FT DIA, 8.8FT HT	1	561905.	396238.
THICKENER OVERFLOW PUMPS	490.GPM, 75.0FT HEAD, 15.HP, 1 OPERATING AND 1 SPARE	2	6141.	566.
THICKENER OVERFLOW TANK	8088.GAL, 12.3FT DIA, 8.8FT HT	1	1764.	4231.
FILTER FEED SLURRY PUMP	116.GPM, 50FT HEAD, 3.HP, 2 OPERATING AND 1 SPARE	3	10815.	2216.
FILTER	307.SQ FT FILTRATION AREA	2	193446.	17846.
FILTRATE PUMP (PER FILTER)	59.GPM, 20.0FT HEAD, 0.HP, 2 OPERATING AND 2 SPARE	4	6513.	601.
FILTRATE SURGE TANK	1952.GAL, 6.9FT DIA, 6.9FT HT	1	713.	1711.
FILTRATE SURGE TANK PUMP	118.GPM, 85.0FT HEAD, 4.HP, 1 OPERATING AND 1SPARE	2	4144.	382.
TOTAL EQUIPMENT COST			833724.	459416.

TABLE 10. SAMPLE FIRST-YEAR REVENUE REQUIREMENTS FOR SLUDGE FIXATION ALTERNATIVE

(SLUDGE OPTION 4)

LIMESTONE SLURRY PROCESS -- BASIS: 500 MW UNIT, 1980 STARTUP

PROJECTED REVENUE REQUIREMENTS - BASE CASE EXAMPLE 500 MW CASE 007

DISPLAY SHEET FOR YEAR= 1
ANNUAL OPERATION KW-HR/KW = 4512

30.75 TONS PER HOUR DRY SLUDGE
TOTAL FIXED INVESTMENT 45720000

	ANNUAL QUANTITY	UNIT COSTS	TOTAL ANNUAL COSTS
DIRECT COSTS			
RAW MATERIAL			
LIMESTONE	107.5 K TONS	8.00/TON	859900
LIME	0.0 K TONS	40.00/TON	0
SUBTOTAL RAW MATERIAL			859900
CONVERSION COSTS			
OPERATING LABOR AND SUPERVISION	32930.0 MAN-HR	12.00/MAN-HR	395100
UTILITIES			
STEAM	413440.0 K LB	1.70/K LB	702900
PROCESS WATER	144220.0 K GAL	0.12/K GAL	17300
ELECTRICITY	39015960.0 KWH	0.030/KWH	1170500
MAINTENANCE LABOR AND MATERIAL			1628300
ANALYSES	2420.0 HR	17.00/HR	41200
SUBTOTAL CONVERSION COSTS			3955300
SUBTOTAL DIRECT COSTS			4815200
INDIRECT COSTS			
DEPRECIATION			1483400
COST OF CAPITAL AND TAXES, 17.20% OF UNDEPRECIATED INVESTMENT			7863900
INSURANCE & INTERIM REPLACEMENTS, 1.17% OF TOTAL CAPITAL INVESTMENT			534900
OVERHEAD			
PLANT, 50.0% OF CONVERSION COSTS LESS UTILITIES			1032300
ADMINISTRATIVE, RESEARCH, AND SERVICE, 10.0% OF OPERATING LABOR AND SUPERVISION			39500
SUBTOTAL INDIRECT COSTS			10954000
SUBTOTAL ANNUAL REVENUE REQUIREMENT			15769200
SLUDGE FIXATION COSTS	138700.0 TONS	15.00/TON	2080500
TOTAL ANNUAL REVENUE REQUIREMENT			17849700
EQUIVALENT UNIT REVENUE REQUIREMENT, MILLS/KWH			7.91

HEAT RATE 9000. BTU/KWH - HEAT VALUE OF COAL 10500 BTU/LB - COAL RATE 966900 TONS/YR

TABLE 11. SAMPLE LIFETIME REVENUE REQUIREMENTS FOR SLUDGE FIXATION ALTERNATIVE

(SLUDGE OPTION 4)

LIMESTONE SLURRY PROCESS -- BASIS: 500 MW UNIT, 1980 STARTUP

PROJECTED LIFETIME REVENUE REQUIREMENTS - BASE CASE EXAMPLE 500 MW

CASE 007

TOTAL CAPITAL INVESTMENT: $ 48720000

YEARS AFTER UNIT START	ANNUAL OPERATION, KW-HR /KW	POWER UNIT HEAT REQUIREMENT, MILLION BTU /YEAR	POWER UNIT FUEL CONSUMPTION, TONS COAL /YEAR	SULFUR REMOVED BY POLLUTION CONTROL PROCESS, TONS/YEAR	BYPRODUCT RATE, EQUIVALENT TONS/YEAR DRY SLUDGE	SLUDGE FIXATION FEE $/TON DRY SLUDGE	ADJUSTED GROSS ANNUAL REVENUE REQUIREMENT EXCLUDING SLUDGE FIXATION COST, $/YEAR	TOTAL ANNUAL SLUDGE FIXATION COST, $/YEAR	NET ANNUAL INCREASE IN TOTAL REVENUE REQUIREMENT, $	CUMULATIVE NET INCREASE IN TOTAL REVENUE REQUIREMENT, $
1	4912	20304000	966900	24300	138700	15.00	15769200	2080500	17849700	17849700
2	4643	20893500	994900	25000	142800	15.00	15647200	2142000	17789200	35638900
3	4775	21487500	1023200	25800	146800	15.00	15525500	2202000	17727500	53366400
4	4906	22077000	1051300	26500	150900	15.00	15402000	2263500	17665500	71031900
5	5037	22666500	1079600	27200	156200	15.00	15278300	2323500	17601800	88633200
6	5169	23260500	1107600	27900	158900	15.00	15154900	2383500	17538400	106172100
7	5300	23850000	1135700	28600	163000	15.00	15030200	2445000	17475200	123647300
8	5432	24444000	1164000	29300	167000	15.00	14905700	2505000	17410700	141058000
9	5563	25033500	1192100	30000	171100	15.00	14779900	2566500	17346400	158404400
10	5694	25623000	1220100	30700	175100	15.00	14653300	2626500	17280000	175684400
11	5695	25627500	1220400	30700	175100	15.00	14399300	2626500	17025800	192710200
12	5695	25627500	1220400	30700	175100	15.00	14144100	2626500	16770600	209480800
13	5695	25627500	1220400	30700	175100	15.00	13889000	2626500	16515500	225996300
14	5695	25627500	1220400	30700	175100	15.00	13633800	2626500	16260300	242256600
15	5695	25627500	1220400	30700	175100	15.00	13378700	2626500	16005200	258261800
16	5537	24916500	1186500	29900	170300	15.00	12968100	2554500	15522600	273784400
17	5379	24205500	1152600	29000	165400	15.00	12556900	2481000	15037900	288822300
18	5221	23494500	1118800	28200	160500	15.00	12145000	2407500	14552500	303374800
19	5064	22788000	1085100	27300	155700	15.00	11733200	2335500	14068700	317443500
20	4906	22077000	1051300	26500	150900	15.00	11319700	2263500	13583200	331026700
21	4748	21366000	1017400	25600	146000	15.00	10905200	2190000	13095200	344121900
22	4591	20659500	983800	24800	141200	15.00	10491500	2118000	12609500	356731400
23	4433	19948500	949900	23900	136300	15.00	10075500	2044500	12120000	368851400
24	4275	19237500	916100	23100	131500	15.00	9658400	1972500	11630900	380482300
25	4118	18531000	882400	22200	126600	15.00	9241700	1899000	11140700	391623000
26	3960	17820000	848600	21400	121800	15.00	8822600	1827000	10649600	402272600
27	3802	17109000	814700	20500	116900	15.00	8402700	1753500	10156200	412428800
28	3645	16402500	781100	19700	112100	15.00	7982500	1681500	9664000	422092800
29	3487	15691500	747200	18800	107200	15.00	7559900	1608000	9167900	431260700
30	3329	14980500	713400	18000	102600	15.00	7136100	1536000	8672100	439932800
TOT	146001	657004500	31286100	787700	4489500		372590300	67342500	439932800	
LIFETIME AVERAGE INCREASE IN UNIT REVENUE REQUIREMENT										
DOLLARS PER TON OF COAL BURNED							11.91	2.15	14.06	
MILLS PER KILOWATT-HOUR							5.10	0.93	6.03	
CENTS PER MILLION BTU HEAT INPUT							56.71	10.25	66.96	
DOLLARS PER TON OF SULFUR REMOVED							473.01	85.49	558.50	
REVENUE REQUIREMENT DISCOUNTED AT 11.6% TO INITIAL YEAR, DOLLARS							119562900	19336400	138900300	
LEVELIZED INCREASE IN UNIT REVENUE REQUIREMENT EQUIVALENT TO DISCOUNTED REQUIREMENT OVER LIFE OF POWER UNIT										
DOLLARS PER TON OF COAL BURNED							13.31	2.15	15.46	
MILLS PER KILOWATT-HOUR							5.70	0.93	6.63	
CENTS PER MILLION BTU HEAT INPUT							63.38	10.25	73.63	
DOLLARS PER TON OF SULFUR REMOVED							528.81	85.52	614.33	

ISLUDG = 1

ISLUDG = 2

ISLUDG = 3 SDFEE = 15

ISLUDG = 4 SDFEE = 15

Pond Design Option

Line No.	Input Data
10	1 0 500 3500 25 25 5280 1 12 2.5

PSAMAX PDEPTH PMXEXC

Disposal pond size is calculated based on a square configuration with a diverter dike three-fourths the length of one side. A pond construction diagram is shown in Figure 1. The pond model is based on either unlined, clay-lined, or synthetic-lined design and includes the following options in running the program.

Fixed-depth pond

Optimum-depth pond based on minimum pond investment

Optimum-depth pond based on minimum pond investment with available acreage and maximum excavation depth as overriding constraints.

The optimum-size pond is calculated to minimize the sum of construction cost and land cost by using the optimum depth to area ratio. The input variables are PSAMAX, PDEPTH, and PMXEXC. PSAMAX is the maximum available area for construction of the pond. Pond depth, PDEPTH, is the ultimate depth of the contained waste. Excavation depth, PMXEXC, is the depth of topsoil and clay which is excavated over the entire area of the pond construction site for construction of the enclosing dike. In calculating the amount of excavation, it is assumed that the material excavated compacts to 85% of the actual volume excavated. If PSAMAX is set to zero, pond depth (PDEPTH) is a user-supplied input variable and excavation depth (PMXEXC) is calculated. If the calculated excavation depth (PMXEXC) exceeds the input value, however, excavation is set equal to PMXEXC and pond depth is calculated. If PXAMAX is set to a nonzero value, the optimum size-versus-cost pond is designed within the constraint of maximum available area (PSAMAX) for the pond.

In the event that the input value for PSAMAX is not large enough, the pond printout will be incomplete. Because of this, values of sufficient magnitude must be entered to allow the optimum pond size to be used. For most cases, values of PSAMAX = 9999, PDEPTH = 25, and PMXEXC = 25 will allow optimum pond calculation. The pond design results for the base case are shown in Appendix C. Table 12 shows sample output for a fixed-depth pond rather than an optimum pond.

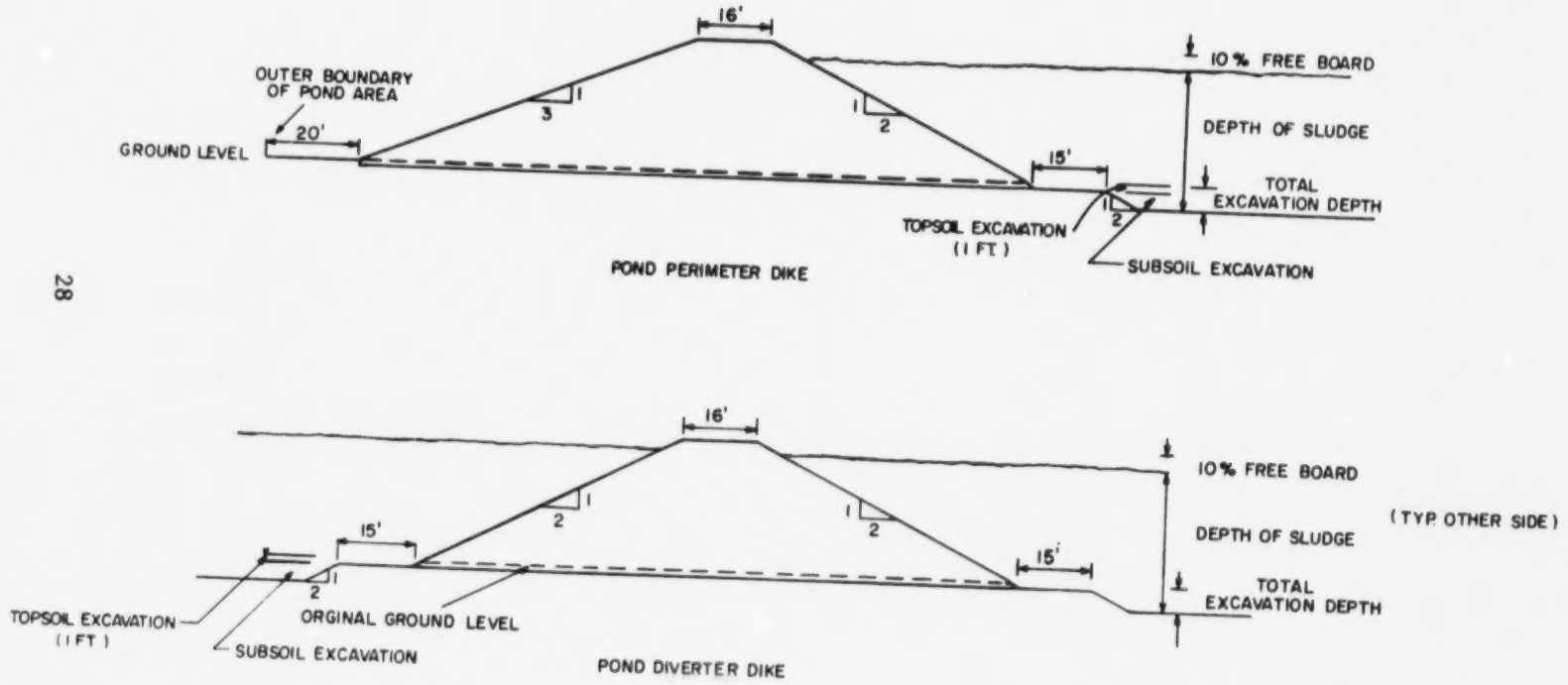


Figure 1. Pond dike construction details.

TABLE 12. FIXED POND DEPTH EXAMPLE

POND DESIGNED FOR FIXED POND DEPTH

POND DIMENSIONS

DEPTH OF POND	25.00	FT
DEPTH OF EXCAVATION	3.99	FT
LENGTH OF PERIMETER	13758.	FT
LENGTH OF DIVIDER	2498.	FT
AREA OF BOTTOM	1154.	THOUSAND YD2
AREA OF INSIDE WALLS	157.	THOUSAND YD2
AREA OF OUTSIDE WALLS	122.	THOUSAND YD2
AREA OF POND	1299.	THOUSAND YD2
AREA OF POND SITE	1474.	THOUSAND YD2
AREA OF POND SITE	305.	ACRES
VOLUME OF EXCAVATION	1637.	THOUSAND YD3
VOLUME OF SLUDGE TO BE DISPOSED OVER LIFE OF PLANT	10269.	THOUSAND YD3
	6365.	ACRE FT

POND COSTS (THOUSANDS OF DOLLARS)

	LABOR	MATERIAL	TOTAL
CLEARING LAND	455.		455.
EXCAVATION	3053.		3053.
DIKE CONSTRUCTION	1222.		1222.
LINING(12. IN. CLAY)	1092.		1092.
SODDING DIKE WALLS	69.	56.	125.
ROAD CONSTRUCTION	8.	17.	25.
POND CONSTRUCTION	5899.	74.	5973.
LAND COST			1066.
POND SITE			7039.
OVERHEAD			4061.
TOTAL			11100.

Pond Liner Option

Line No.	Input Data
10	1 0 500 3500 25 25 5280 1 12 2.5

ILINER XLINA XLINB

The pond liner option allows a choice of an unlined, clay-lined, or synthetic-lined pond. The input variables are ILINER, XLINA, and XLINB. ILINER specifies the type of lining in the pond as illustrated below.

1 = Clay liner

2 = Synthetic liner

3 = No liner

XLINA specifies the depth of clay in inches for a clay-lined pond. For ILINER = 2, XLINA specifies the material unit cost in $\$/yd^2$ for a synthetic liner. XLINB specifies either the clay cost (installed) in $\$/yd^3$ for the clay-lined pond option or the labor unit cost in $\$/yd^2$ for installing the synthetic liner.

Table 12 also shows the base case printout corresponding to a clay-lined pond. An example of the synthetic-lined pond option is illustrated in Table 13 for comparison.

For this synthetic-lined pond option example the values of the inputs are as follows:

ILINER = 2 XLINA = 0.50 XLINB = 1.25

The unlined pond option requires input values of zero for XLINA and XLINB.

Pond Capacity Option

Line No.	Input Data
13	2 1 5 .8 2.0 3 65 1 2 1.10 1979 240.2

PNDCAP

TABLE 13. SYNTHETIC POND LINER EXAMPLE

POND DESIGN

OPTIMIZED TO MINIMIZE TOTAL COST PLUS OVERHEAD

POND DIMENSIONS

DEPTH OF POND	45.75	FT
DEPTH OF EXCAVATION	11.34	FT
LENGTH OF PERIMETER	10575.	FT
LENGTH OF DIVIDER	1846.	FT
AREA OF BOTTOM	587.	THOUSAND YD2
AREA OF INSIDE WALLS	195.	THOUSAND YD2
AREA OF OUTSIDE WALLS	152.	THOUSAND YD2
AREA OF POND	765.	THOUSAND YD2
AREA OF POND SITE	956.	THOUSAND YD2
AREA OF POND SITE	198.	ACRES
VOLUME OF EXCAVATION	2388.	THOUSAND YD3
VOLUME OF SLUDGE TO BE DISPOSED OVER LIFE OF PLANT	10269.	THOUSAND YD3
	6365.	ACRE FT

POND COSTS (THOUSANDS OF DOLLARS)

	LABOR	MATERIAL	TOTAL
CLEARING LAND	295.		295.
EXCAVATION	4455.		4455.
DIKE CONSTRUCTION	2197.		2197.
LINING(SYNTHETIC)	2346.	3911.	6257.
SODDING DIKE WALLS	38.	31.	69.
ROAD CONSTRUCTION	6.	13.	19.
POND CONSTRUCTION	9337.	3955.	13291.
LAND COST			691.
POND SITE			13983.
OVERHEAD			9038.
TOTAL			23021.

The pond capacity option provides the capability to design the raw material and scrubber areas based on maximum sulfur content of coal (high sulfur content fluctuation) but, at the same time, to design the pond based on an average sulfur content. For example, on a long-term basis, the coal being used may be expected to average 2.0% sulfur. However, at times the sulfur content may be as high as 3%. The raw material preparation area and the scrubbers should be sized for the maximum coal sulfur content that is expected to be encountered. In this case a value of 3% must be considered for design of the feed preparation and scrubber units, but the model also calculates the sludge production rate based on the input sulfur content and sizes the pond based on that amount. The PNDCAP option is included in the model to allow the projected waste disposal pond size to be modified to account for the difference between average and maximum sulfur content (ordinarily PNDCAP will be in the range of 0.5-1.0). In the example above, by inputting PNDCAP equal to 0.67, the waste disposal pond would be sized based on a 2% sulfur coal, whereas the other facilities would be designed for fluctuations in sulfur content to 3% sulfur in the coal.

If the user wishes to specify an oversized pond to cover contingencies in sulfur content, an appropriate PNDCAP factor, i.e., greater than 1.0, can be specified.

Operating Profile Option

Line No.	Input Data
13	2 1 5 .8 2.0 3 65 1 2 1.10 1979 240.2 ↘ IOPSCH
14	30 ↘ IYROP

One of the most important variables affecting the economics of a power plant and an associated FGD system is the operating profile (number of years of operation and the hours of operation per year) over the life of the unit. The model provides three options for specifying this profile. The input variable for these options is IOPSCH. If IOPSCH = 1 the program uses the TVA-developed operating schedule shown in Figure 2 which is based on the profile assumed in *Detailed Cost Estimates for Advanced Effluent Desulfurization Processes* (5). If IOPSCH = 2 the operating schedule is based on historical Federal Energy Regulatory Comission (FERC, previously FPC) data as shown in Figure 3. If IOPSCH = 3 the user must input the operating profile (hr/yr, 7000 for example) beginning on line 15. The total number of entries beginning on line 15 must equal the input variable IYROP located on line 14, where IYROP indicates the years of life expected for the unit. The number of entries per line must not exceed 10. A line with less than 10 entries is acceptable if it is the last line required to complete the number of years required. An example is shown below.

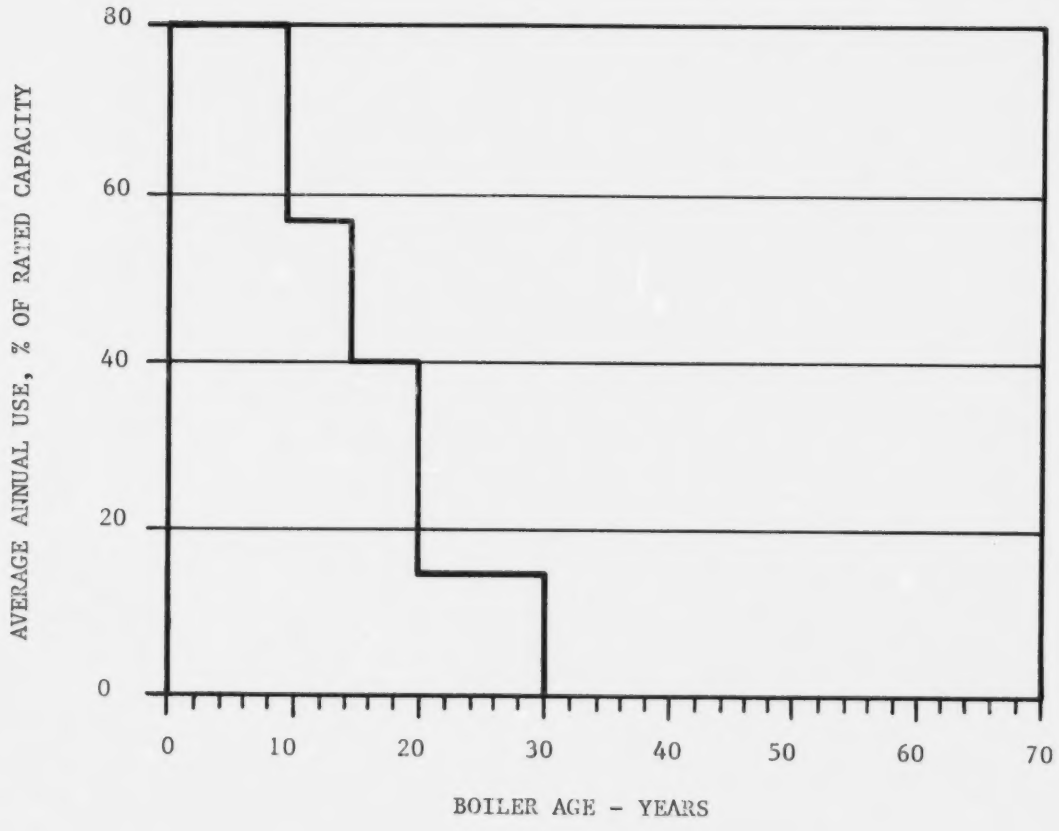


Figure 2. Operating profile assumed for IOPSCH = 1.

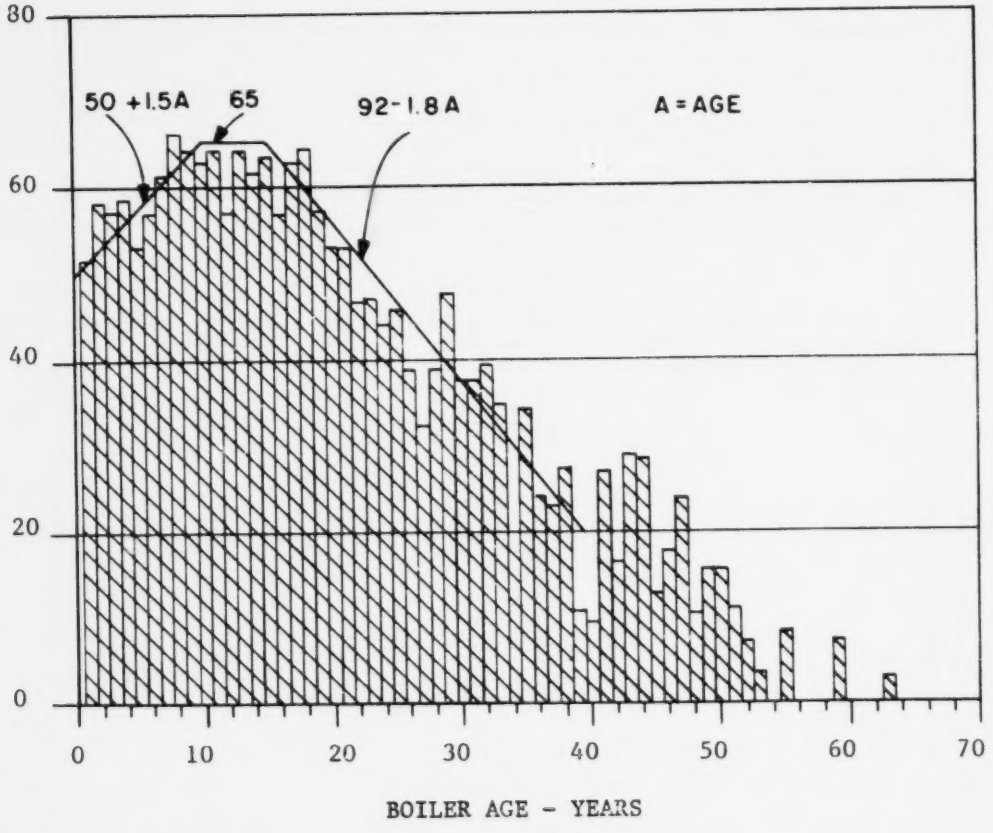


Figure 3. Operating profile assumed for IOPSCH = 2 based on Federal Energy Regulatory Commission 1969-1973 data.

Line No.	Input Data
13	3 1 5 .8 2.0 3 65 1 2 1.10 1979 240.2
14	25
15	5000 5000 6000 6000 7000 7000 7000 7000 7000 7000
16	7000 7000 7000 7000 7000 7000 7000 7000 6000 6000
17	6000 5000 5000 5000 4000
18	END

Sample output resulting from the Figure 1 operating profile (IOPSCH = 1) is shown in Table 14. The sample base case printout in Appendix C illustrates the results of the Figure 2 FERC data operating profile (IOPSCH = 2). Sample output resulting from a user-supplied operating profile (IOPSCH = 3) is shown in Table 15.

USAGE OF THE MODEL

As previously discussed, a copy of the model can be made available for independent user execution. As an alternative to obtaining the program, TVA, under an information-exchange agreement with EPA, can make specific runs of the model based on user-supplied input data. The remainder of this section is provided for potential users who wish to obtain the model for independent use.

The model was developed for, and is executed on, the TVA in-house IBM computer system (370/165). The current model consists of two FORTRAN programs that are compiled using either the IBM G1 or H extended compiler. The first program is relatively large; it contains about 8000 lines of source code. The second program contains about 2000 lines.

Core storage requirements for the first program are about 250,000 bytes; the use of overlays can reduce this requirement to 150,000 bytes. The second program executes within 150,000 bytes of core storage with no overlays. Sample control cards for creating an overlay structure for the first program are shown in Table 16. A conceptual map of the internal program is shown in Figure 4. The map reflects the subroutine calling sequence in the order of left to right and top to bottom.

In addition to the core storage required for program execution, temporary online storage (disk) is also required for intermediate files and the transfer of data between the two programs. The only input data required for model execution is the user input data; all other data for default assumptions and option-related calculations are assigned the necessary values internally within the program. Temporary online storage requirements depend on the number of cases run but typically do not exceed 200,000 bytes.

TABLE 14. SAMPLE OUTPUT USING THE DETAILED COST ESTIMATES OPERATING PROFILE

LIMESTONE SLURRY PROCESS -- BASIS: 500 MW UNIT, 1980 STARTUP

PROJECTED LIFETIME REVENUE REQUIREMENTS - BASE CASE EXAMPLE 500 MW CASE 010

TOTAL CAPITAL INVESTMENT: $ 54279000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION, KW-HR /KW	POWER UNIT HEAT REQUIREMENT, MILLION BTU /YEAR	POWER UNIT FUEL CONSUMPTION, TONS COAL /YEAR	SULFUR REMOVED BY POLLUTION CONTROL PROCESS, TONS/YEAR	BYPRODUCT RATE, EQUIVALENT TONS/YEAR DRY SLUDGE	SLUDGE FIXATION FEE $/TON DRY SLUDGE	ADJUSTED GROSS ANNUAL REVENUE REQUIREMENT EXCLUDING SLUDGE FIXATION COST, $/YEAR	TOTAL ANNUAL SLUDGE FIXATION COST, $/YEAR	NET ANNUAL INCREASE IN TOTAL REVENUE REQUIREMENT, $	CUMULATIVE NET INCREASE IN TOTAL REVENUE REQUIREMENT, $
1	7000	31500000	1500000	37800	219700	0.0	19921300	0	19921300	19921300
2	7000	31500000	1500000	37800	219700	0.0	19623300	0	19623300	39544600
3	7000	31500000	1500000	37800	219700	0.0	19325300	0	19325300	58869900
4	7000	31500000	1500000	37800	219700	0.0	19027200	0	19027200	77897100
5	7000	31500000	1500000	37800	219700	0.0	18729200	0	18729200	96626300
6	7000	31500000	1500000	37800	219700	0.0	18431200	0	18431200	115057500
7	7000	31500000	1500000	37800	219700	0.0	18133200	0	18133200	133190700
8	7000	31500000	1500000	37800	219700	0.0	17835100	0	17835100	151025800
9	7000	31500000	1500000	37800	219700	0.0	17537100	0	17537100	168562900
10	7000	31500000	1500000	37800	219700	0.0	17239100	0	17239100	185802000
11	5000	22500000	1071400	27000	156900	0.0	15000300	0	15000300	200802300
12	5000	22500000	1071400	27000	156900	0.0	14702200	0	14702200	215504500
13	5000	22500000	1071400	27000	156900	0.0	14404200	0	14404200	229908700
14	5000	22500000	1071400	27000	156900	0.0	14106200	0	14106200	244014900
15	5000	22500000	1071400	27000	156900	0.0	13808200	0	13808200	257823100
16	3500	15750000	750000	18900	109900	0.0	11975900	0	11975900	269799000
17	3500	15750000	750000	18900	109900	0.0	11677900	0	11677900	281476900
18	3500	15750000	750000	18900	109900	0.0	11379900	0	11379900	292856800
19	3500	15750000	750000	18900	109900	0.0	11081900	0	11081900	303938700
20	3500	15750000	750000	18900	109900	0.0	10783800	0	10783800	314722500
21	1500	6750000	321400	8100	47100	0.0	8234500	0	8234500	322957000
22	1500	6750000	321400	8100	47100	0.0	7936500	0	7936500	330893500
23	1500	6750000	321400	8100	47100	0.0	7638500	0	7638500	338532000
24	1500	6750000	321400	8100	47100	0.0	7340400	0	7340400	345872400
25	1500	6750000	321400	8100	47100	0.0	7042400	0	7042400	352916800
26	1500	6750000	321400	8100	47100	0.0	6744400	0	6744400	359659200
27	1500	6750000	321400	8100	47100	0.0	6446400	0	6446400	366105600
28	1500	6750000	321400	8100	47100	0.0	6148300	0	6148300	372253900
29	1500	6750000	321400	8100	47100	0.0	5850300	0	5850300	378104200
30	1500	6750000	321400	8100	47100	0.0	5552300	0	5552300	383656500
TOT	127500	573750000	27321000	688500	4002000		383656500	0	383656500	

LIFETIME AVERAGE INCREASE IN UNIT REVENUE REQUIREMENT

DOLLARS PER TON OF COAL BURNED	14.04	0.0	14.04
MILLS PER KILOWATT-HOUR	6.02	0.0	6.02
CENTS PER MILLION BTU HEAT INPUT	66.87	0.0	66.87
DOLLARS PER TON OF SULFUR REMOVED	557.24	0.0	557.24

REVENUE REQUIREMENT DISCOUNTED AT 11.6% TO INITIAL YEAR, DOLLARS 138433200 0 138433200

LEVELIZED INCREASE IN UNIT REVENUE REQUIREMENT EQUIVALENT TO DISCOUNTED REQUIREMENT OVER LIFE OF POWER UNIT

DOLLARS PER TON OF COAL BURNED	13.00	0.0	13.00
MILLS PER KILOWATT-HOUR	5.57	0.0	5.57
CENTS PER MILLION BTU HEAT INPUT	61.90	0.0	61.90
DOLLARS PER TON OF SULFUR REMOVED	515.77	0.0	515.77

TABLE 15. SAMPLE OUTPUT USING A USER-SUPPLIED OPERATING PROFILE

LIMESTONE SLURRY PROCESS -- BASIS: 500 MW UNIT, 1980 STARTUP

PROJECTED LIFETIME REVENUE REQUIREMENTS - BASE CASE EXAMPLE 500 MW

CASE 011

TOTAL CAPITAL INVESTMENT: $ 36523000

YEARS AFTER UNIT START	ANNUAL OPERATION, KW-HR /KW	POWER UNIT HEAT REQUIREMENT, MILLION BTU /YEAR	POWER UNIT FUEL CONSUMPTION, TONS COAL /YEAR	SULFUR REMOVED BY POLLUTION CONTROL PROCESS, TONS/YEAR	BYPRODUCT RATE, EQUIVALENT TONS/YEAR DRY SLUDGE	SLUDGE FIXATION FEE $/TON DRY SLUDGE	ADJUSTED GROSS ANNUAL REVENUE REQUIREMENT EXCLUDING SLUDGE FIXATION COST, $/YEAR	TOTAL ANNUAL SLUDGE FIXATION COST, $/YEAR	NET ANNUAL INCREASE IN TOTAL REVENUE REQUIREMENT, $	CUMULATIVE NET INCREASE IN TOTAL REVENUE REQUIREMENT, $
1	6000	27000000	1285700	32400	188300	0.0	19489500	0	19489500	19489500
2	6000	27000000	1285700	32400	188300	0.0	19180000	0	19180000	38669500
3	6000	27000000	1285700	32400	188300	0.0	18870600	0	18870600	57540100
4	6000	27000000	1285700	32400	188300	0.0	18561200	0	18561200	76101300
5	6000	27000000	1285700	32400	188300	0.0	18251800	0	18251800	94353100
6	6000	27000000	1285700	32400	188300	0.0	17942300	0	17942300	112295400
7	6000	27000000	1285700	32400	188300	0.0	17632900	0	17632900	129928300
8	6000	27000000	1285700	32400	188300	0.0	17323500	0	17323500	147251800
9	6000	27000000	1285700	32400	188300	0.0	17014100	0	17014100	164269900
10	6000	27000000	1285700	32400	188300	0.0	16706600	0	16706600	180976500
11	6500	29250000	1392900	35100	204000	0.0	16879600	0	16879600	197850100
12	6500	29250000	1392900	35100	204000	0.0	16570200	0	16570200	214420300
13	6500	29250000	1392900	35100	204000	0.0	16260700	0	16260700	230681000
14	6500	29250000	1392900	35100	204000	0.0	15951300	0	15951300	246632300
15	6500	29250000	1392900	35100	204000	0.0	15641900	0	15641900	262274200
16	6500	29250000	1392900	35100	204000	0.0	15332500	0	15332500	277606700
17	6500	29250000	1392900	35100	204000	0.0	15023000	0	15023000	292629700
18	6500	29250000	1392900	35100	204000	0.0	14713600	0	14713600	307343300
19	6500	29250000	1392900	35100	204000	0.0	14404200	0	14404200	321747500
20	6500	29250000	1392900	35100	204000	0.0	14094700	0	14094700	335842200
21	5000	22500000	1071400	27000	156900	0.0	12313900	0	12313900	348156100
22	5000	22500000	1071400	27000	156900	0.0	12004500	0	12004500	360160600
23	5000	22500000	1071400	27000	156900	0.0	11695100	0	11695100	371855700
24	5000	22500000	1071400	27000	156900	0.0	11385600	0	11385600	383241300
25	5000	22500000	1071400	27000	156900	0.0	11076200	0	11076200	394317500
26	4000	18000000	857100	21600	125500	0.0	9768500	0	9768500	404086000
27	3000	13500000	642900	16200	94200	0.0	8377800	0	8377800	412463800
28	3000	13500000	642900	16200	94200	0.0	8068400	0	8068400	420512200
29	3000	13500000	642900	16200	94200	0.0	7759000	0	7759000	428271200
30	3000	13500000	642900	16200	94200	0.0	7449600	0	7449600	435720800
TOT	166000	747000000	35571700	896400	5209800		435720800	0	435720800	

LIFETIME AVERAGE INCREASE IN UNIT REVENUE REQUIREMENT

DOLLARS PER TON OF COAL BURNED	12.25	0.0	12.25
MILLS PER KILOWATT-HOUR	5.25	0.0	5.25
CENTS PER MILLION BTU HEAT INPUT	58.33	0.0	58.33
DOLLARS PER TON OF SULFUR REMOVED	486.08	0.0	486.08

REVENUE REQUIREMENT DISCOUNTED AT 11.6% TO INITIAL YEAR, DOLLARS 142473300 0 142473300

LEVELIZED INCREASE IN UNIT REVENUE REQUIREMENT EQUIVALENT TO DISCOUNTED REQUIREMENT OVER LIFE OF POWER UNIT

DOLLARS PER TON OF COAL BURNED	13.38	0.0	13.38
MILLS PER KILOWATT-HOUR	5.73	0.0	5.73
CENTS PER MILLION BTU HEAT INPUT	63.69	0.0	63.69
DOLLARS PER TON OF SULFUR REMOVED	530.82	0.0	530.82

TABLE 16. LINKAGE-EDITOR CONTROL CARDS FOR THE SHAWNEE LIME-LIMESTONE COMPUTER PROGRAM

```
00010   ENTRY MAIN
00020   OVERLAY ORG1
00030  INSERT  PNDDEP,PNDCP
00040   OVERLAY ORG1
00050  INSERT ZERO
00060   OVERLAY ORG1
00070  INSERT  READIN,RELDSP
00080   OVERLAY ORG1
00090  INSERT  BECHTL
00100   OVERLAY ORG2
00110  INSERT  DUST,PRIN,MBCON,HOTGAS
00120   OVERLAY ORG2
00130  INSERT  SO2ELM,MATBAL,PHIN,STOICH
00140   OVERLAY ORG2
00150  INSERT  CLARIF,WETGAS,CSA,REHEAT,STMRHT,STKGAS,PDROP
00160   OVERLAY ORG2
00170  INSERT  PNDSGN
00180   OVERLAY ORG2
00190  INSERT  STREAM
00200   OVERLAY ORG2
00210  INSERT  H2OBAL,CSAFIL
00220   OVERLAY ORG1
00230  INSERT  PROUT
00240   OVERLAY ORG1
00250  INSERT  TVAIN
00260   OVERLAY ORG4
00270  INSERT  EQUIPT
00280   OVERLAY ORG5
00290  INSERT  VENTUR
00300   OVERLAY ORG5
00310  INSERT  LSPREP
00320   OVERLAY ORG5
00330  INSERT  LIMEPR
00340   OVERLAY ORG5
00350  INSERT  THICK,FILTER,TANKS,SLPUMP,PREPSM
00360   OVERLAY ORG5
00370  INSERT  MECOLL,FANS,SCRUBB,REHETR,SOOTBL,H2OPMP,EQPSUM
00380   OVERLAY ORG5
00390  INSERT  EQUIPR
00400   OVERLAY ORG4
00410  INSERT  STRUCT,FOUNDT
00420   OVERLAY ORG4
00430  INSERT  PIPES,DUCWRK,INSTRM,LAND
00440   OVERLAY ORG4
00450  INSERT  ELECTR,TOTALS,WORKCP
00460   OVERLAY ORG4
00470  INSERT  PRINTI
00480   OVERLAY ORG4
00490  INSERT  SPRINT
```

(continued)

TABLE 16 (continued)

```
00500   OVERLAY ORG4
00510  INSERT  PARTIC
00520   OVERLAY ORG1
00530  INSERT WRITDS
00540   OVERLAY ORG11(REGION)
00550  INSERT EQCALL,BEQ
00560   OVERLAY ORG12
00570  INSERT  TCON,KCALC
00580   OVERLAY ORG12
00590  INSERT  CASO3,CASO4,CASOX
00600   OVERLAY ORG12
00610  INSERT  BEQPRT
00620   OVERLAY ORG11
00630  *NSERT  PNDOPT,PNDEXC,PNDCST,PNDSZE
00640   OVERLAY ORG11
00650  INSERT  PNDPRT
00660   ALIAS PND
0060  NAME  INV(R)
```

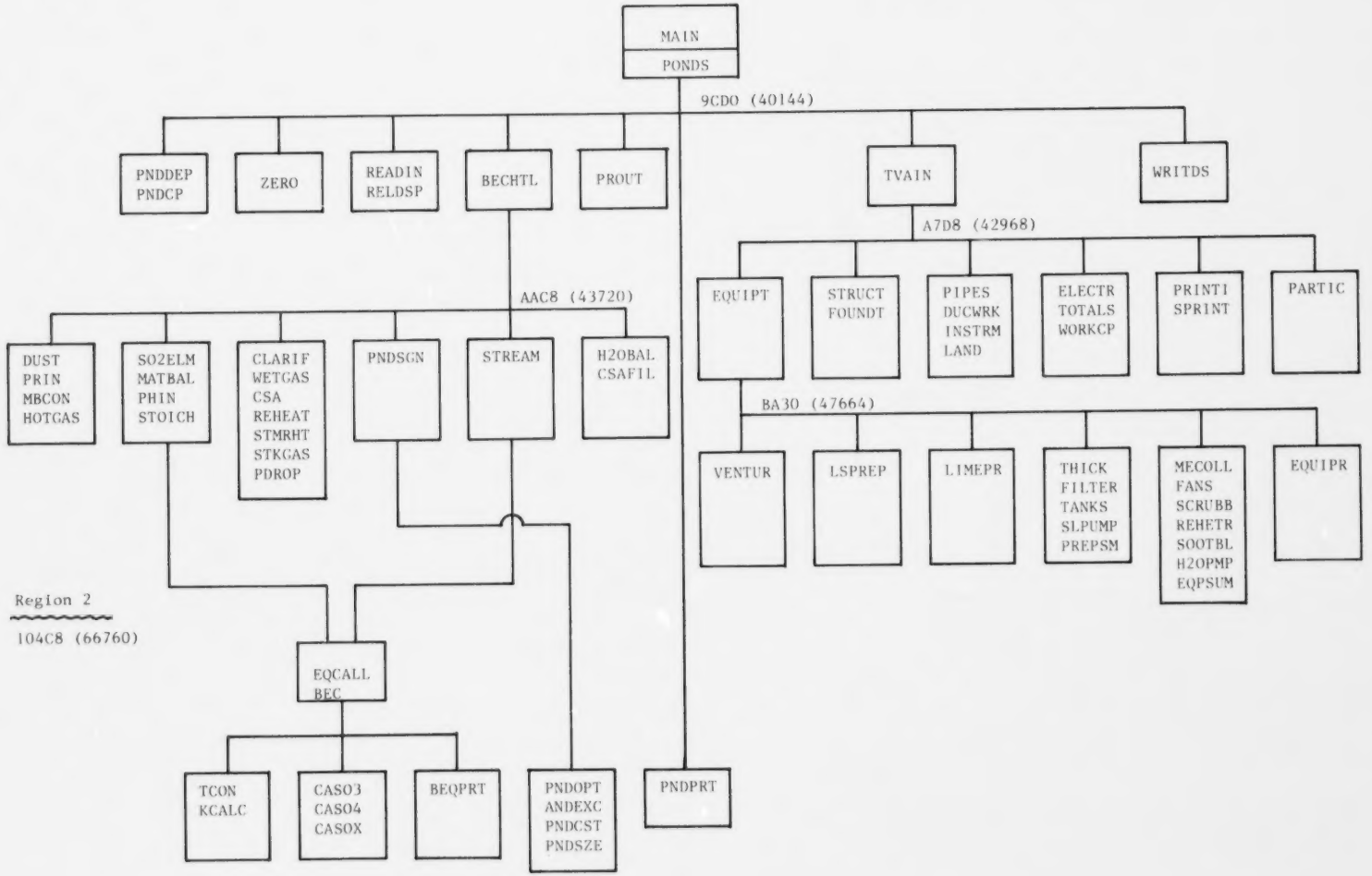


Figure 4. Conceptual map of the model investment program.

The model is executed in both interactive and batch modes. The input data can be provided in three different ways depending on the mode of execution. For batch execution (typically remote batch) the input data variables are punched on cards and inserted in a model execution run deck. The second method of providing data applies to interactive model execution. Input is solicited at the terminal during actual model execution and the user must respond with the appropriate values. The third method is used for both interactive and batch execution. A data file is created interactively (typically using text editor); all variable values (including the options selected) are examined and corrected if necessary; then the model is executed (either interactively or a batch run is submitted) and the input is processed as a standard data file.

The third method of providing input data has been found to be preferable in most cases. When separate but similar model runs are required, the data file containing the input is copied to a second file, any variables and options are modified as necessary, and a second model run is submitted. This reduces both input preparation time and the number of input data errors because only the variables and options that differ from a previous run must be modified.

The job control language (JCL) required to execute the model in batch mode is stored in a catalogued procedure file. A sample procedure file is shown in Table 17. The catalogued procedure uses a system utility program, IEBGENER, which can be replaced if necessary by a user program to copy from input card data to disk storage and from disk storage to an output print file. The overall procedure consists of four steps to (1) copy the input data to a temporary online storage file (disk), (2) copy the input data to an output print file, (3) execute the first program of the model, and (4) execute the second model program. The programs are executed from load modules to avoid recompiling each time they are executed.

The remaining JCL required to execute the model (batch mode) is shown in Table 18. The catalogued procedure (Table 17) is executed and the required input is read from a previously created data file. If the input data have been prepared on cards, a card deck would be submitted (similar to Table 18) with the data cards following the //LOAD.DATA DD * ... card. The JCL example shown in Tables 17 and 18 generally applies whether the job is submitted interactively or by a card deck.

In addition to interactively submitting a model run for batch execution, the model can also be directly executed interactively. The input data can either be entered directly during program execution or it can be provided from a previously created data file. Table 19 shows two sample interactive procedures for model execution. Example 1 in Table 19 shows a sample procedure for directly entering the data during model execution. Example 2 shows a sample procedure for interactive execution using a previously created data file.

TABLE 17. SAMPLE PROCEDURE FOR EXECUTING THE MODEL IN BATCH MODES

```
//SHAWNEE  PROC  PRTFMS=A                                                  ØØØØØØ1Ø
//LOAD     EXEC  PGM=IEBGENER                                              ØØØØØØ2Ø
//SYSPRINT DD  SYSOUT=A                                                    ØØØØØØ3Ø
//SYSIN    DD  DUMMY                                                       ØØØØØØ4Ø
//SYSUT1   DD  DDNAME=DATA                                                 ØØØØØØ5Ø
//SYSUT2   DD  UNIT=SYSCR,SPACE=(TRK,(1,1),RLSE),DISP=(NEW,PASS),         ØØØØØØ6Ø
//            DCB=(RECFM=FB,LRECL=8Ø,BLKSIZE=4ØØ)                          ØØØØØØ7Ø
//LIST     EXEC  PGM=IEBGENER                                              ØØØØØØ8Ø
//SYSPRINT DD  SYSOUT=A                                                    ØØØØØØ9Ø
//SYSIN    DD  DUMMY                                                       ØØØØØ1ØØ
//SYSUT1   DD  DSN=*.LOAD.SYSUT2,DISP=(OLD,PASS)                           ØØØØ11Ø
//SYSUT2   DD  SYSOUT=&PRTFMS,DCB=(RECFM=F,LRECL=8Ø,BLKSIZE=8Ø)            ØØØØ12Ø
//INVEST   EXEC  PGM=INV,REGION=15ØK                                       ØØØØ13Ø
//STEPLIB  DD  DSN=CHM.SHAWNEE.LOAD,DISP=SHR                               ØØØØ14Ø
//FTØ2FØØ1 DD  UNIT=SYSCR,SPACE=(TRK,(1,1),RLSE),DISP=(NEW,PASS),          ØØØØ15Ø
//            DCB=(LRECL=4Ø4,BLKSIZE=4Ø8,RECFM=VBS)                        ØØØØ16Ø
//FTØ3FØØ1 DD  SYSOUT=A                                                    ØØØØ17Ø
//FTØ5FØØ1 DD  DSN=*.LOAD.SYSUT2,DISP=(OLD,DELETE,DELETE)                  ØØØØ18Ø
//FTØ6FØØ1 DD  SYSOUT=&PRTFMS                                              ØØØØ19Ø
//REVENUE  EXEC  PGM=REV,REGION=15ØK,COND=(COND=(Ø,LT,INVEST)               ØØØØ2ØØ
//STEPLIB  DD  DSN=CHM.SHAWNEE.LOAD,DISP=SHR                               ØØØØ21Ø
//FTØ2FØØ1 DD  DSN=*.INVEST.FTØ2FØØ1,DISP=(OLD,DELETE,DELETE)              ØØØØ22Ø
//FTØ6FØØ1 DD  SYSOUT=&PRTFMS                                              ØØØØ23Ø
```

TABLE 18. SAMPLE BATCH RUN TO EXECUTE THE MODEL USING A PROCEDURE FILE

```
//TXSHAWNE  JOB 7Ø1ØØ9,SGROSS. T1Ø2NFDC.2513,MSGLEVEL=1,CLASS=K,    ØØØØØØ1Ø
//              NOTIFY=CHM                                          ØØØØØØ2Ø
/*ROUTE  PRINT REMOTE3                                             ØØØØØØ3Ø
//PROCLIB  DD  DSN=CHM.PROCLIB,DISP=SHR                            ØØØØØØ4Ø
//SHAWNEE EXEC  SHAWNEE,PRTFMS=A                                   ØØØØØØ5Ø
//LOAD.DATA  DD *        INPUT DATA CARDS FOLLOW THIS CARD         ØØØØØØ6Ø
//                                                                 ØØØØØØ7Ø

//TXSHAWNE   JOB 7Ø1ØØ9,SGROSS.T1Ø2NFDC.2513,MSGLEVEL=1,CLASS=K,   ØØØØØØ1Ø
//              NOTIFY=CHM                                         ØØØØØØ2Ø
/*ROUTE  PRINT REMOTE3                                             ØØØØØØ3Ø
//PROCLIB  DD  DSN=CHM.PROCLIB,DISP=SHR                            ØØØØØØ4Ø
//SHAWNEE EXEC  SHAWNEE,PRTFMS=A                                   ØØØØØØ5Ø
//LOAD.DATA  DD  DISP=SHR,DSN=CHM.PART2.DATA                       ØØØØØØ6Ø
//                                                                 ØØØØØØ7Ø
```

TABLE 19. SAMPLE PROCEDURE FOR EXECUTING THE MODEL INTERACTIVELY

```
ØØØ1Ø  FREEALL
ØØØ2Ø  TERM LINESIZE(132)
ØØØ3Ø  FREE FILE (FTØ2FØØ1,FTØ3FØØ1,FTØ5FØØ1,FTØ6FØØ1)
ØØØ4Ø  ALLOC FI(FTØ2FØØ1)  NEW BLOCK(13Ø3Ø)  SPACE(1Ø,5)
ØØØ5Ø  ALLOC FI(FTØ3FØØ1)  DA(*)
ØØØ6Ø  ALLOC FI(FTØ5FØØ1)  DA(*)
ØØØ7Ø  ALLOC FI(FTØ6FØØ1)  DA(*)
ØØØ8Ø  CALL 'CHM.SHAWNEE.LOAD(INV)'
ØØØ9Ø  CALL 'CHM.SHAWNEE.LOAD(REV)'
ØØ1ØØ  FREEALL

ØØØ1Ø  FREEALL
ØØØ2Ø  TERM LINESIZE(132)
ØØØ3Ø  FREE DA('CHM.PART2.DATA')
ØØØ4Ø  FREE FILE(FTØ2FØØ1,FTØ3FØØ1,FTØ5FØØ1,FTØ6FØØ1)
ØØØ5Ø  ALLOC FI(FTØ2FØØ1)  NEW BLOCK(13Ø3Ø)  SPACE(1Ø,5)
ØØØ6Ø  ALLOC FI(FTØ3FØØ1)  DA(*)
ØØØ7Ø  ALLOC FI(FTØ5FØØ1)  DA('CHM.PART2.DATA')
ØØØ8Ø  ALLOC FI(FTØ6FØØ1)  DA(*)
ØØØ9Ø  CALL 'CHM.SHAWNEE.LOAD(INV)'
ØØ1ØØ  CALL 'CHM.SHAWNEE.LOAD(REV)'
ØØ11Ø  FREEALL
```

The amount of computer time required for model execution is a function of the number of cases of input data and the particular computer system. On the TVA system (IBM 370/165) the average CPU time required per case is about 1 second but some cases have exceeded 5 seconds.

The model is usually distributed on magnetic tape for independent usage. A fairly wide range of tape format options is available but typically the tape is unlabeled, the density is 1600, the block size is 4000 characters (50 records, 80 characters per record), and the tape contains 2 files, one for each program.

REFERENCES

1. Torstrick, R. L. Shawnee Limestone-Lime Scrubbing Process Computerized Design Cost Estimates Program: Summary Description Report. Prepared for presentation at Industry Briefing Conference, Raleigh, North Carolina, October 19-21, 1976.

2. Stephenson, C. D., and R. L. Torstrick. Current Status of Development of the Shawnee Lime-Limestone Computer Program. Prepared for presentation at Industry Briefing Conference, Raleigh, North Carolina, August 29, 1978.

3. Torstrick, R. L., L. J. Henson, and S. V. Tomlinson. Economic Evaluation Techniques, Results, and Computer Modeling for Flue Gas Desulfurization. In: Proceedings, Symposium on Flue Gas Desulfurization, Hollywood, Florida, November 1977 (Volume I), F. A. Ayer, ed., EPA-600/7-78-058B, U.S. Environmental Protection Agency, Washington, D.C., 1978 pp.

4. The program that sizes and costs particulate removal devices was provided by Paul Farber of Argonne National Laboratory, Argonne, Illinois.

5. McGlamery, G. G., R. L. Torstrick, W. J. Broadfoot, J. P. Simpson, L. J. Henson, S. V. Tomlinson, and J. F. Young. Detailed Cost Estimates for Advanced Effluent Desulfurization Processes, Bulletin Y-90, Tennessee Valley Authority, Muscle Shoals, Alabama; EPA-600/2-75-006, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1975.

APPENDIX A

PROCESS FLOWSHEETS AND LAYOUTS

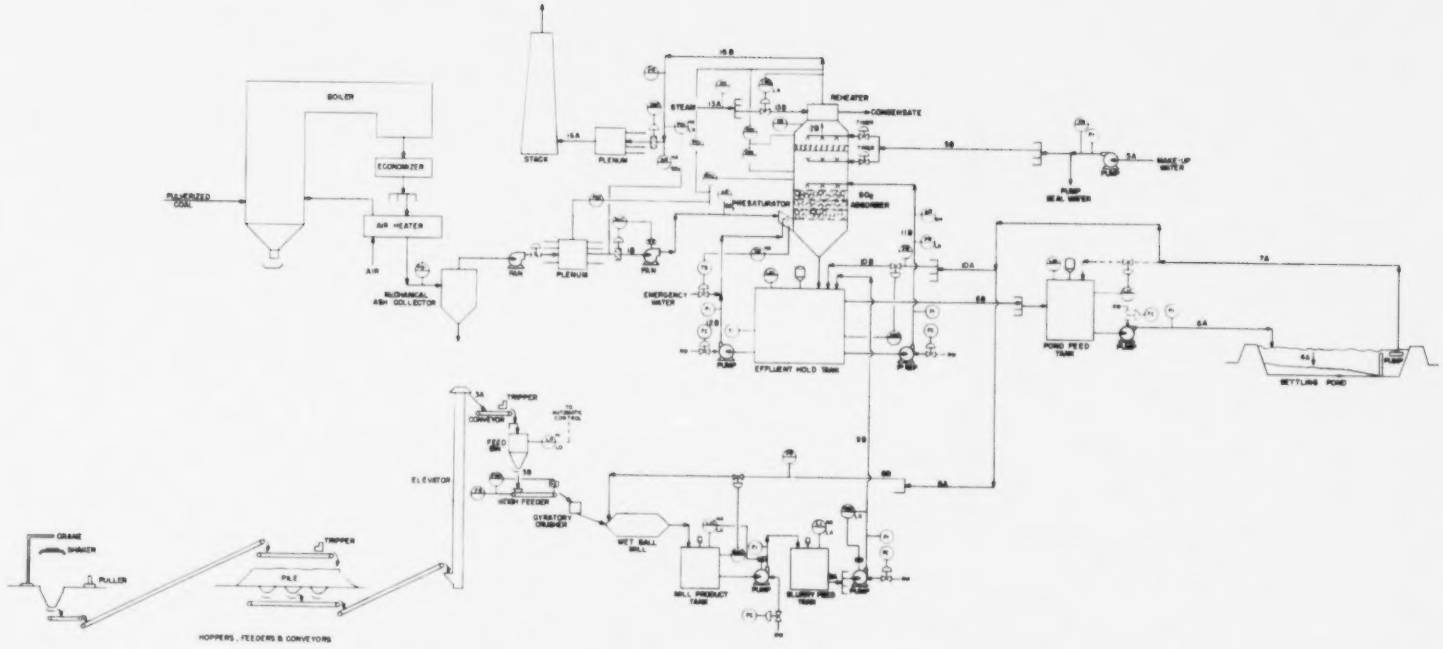


Figure A-1. Limestone scrubbing process utilizing TCA absorber.

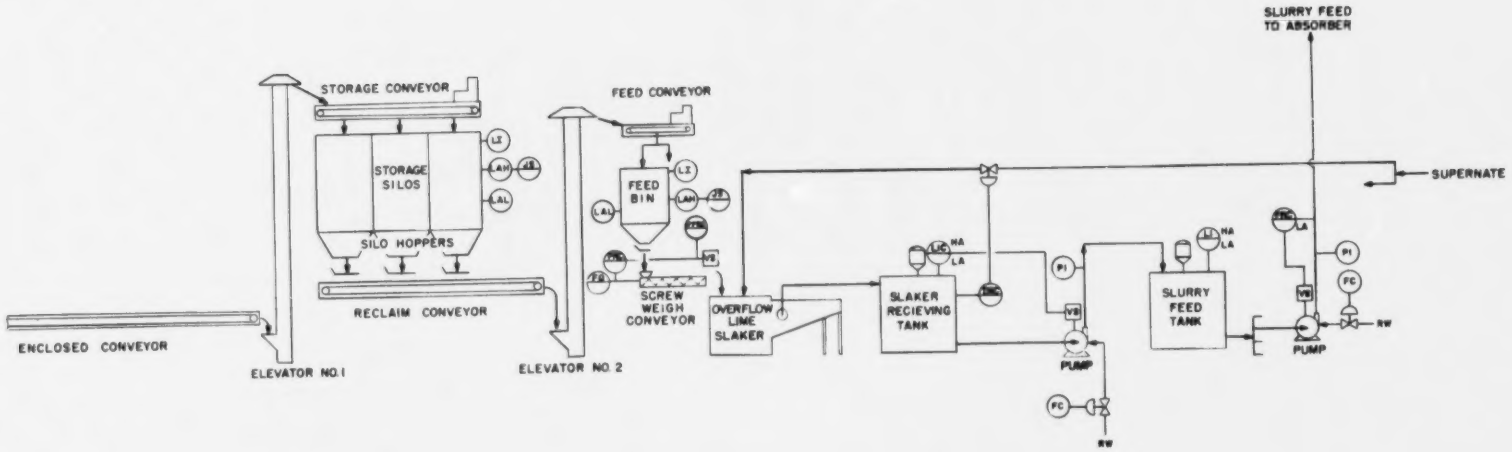


Figure A-2. Lime handling and preparation area for lime scrubbing option.

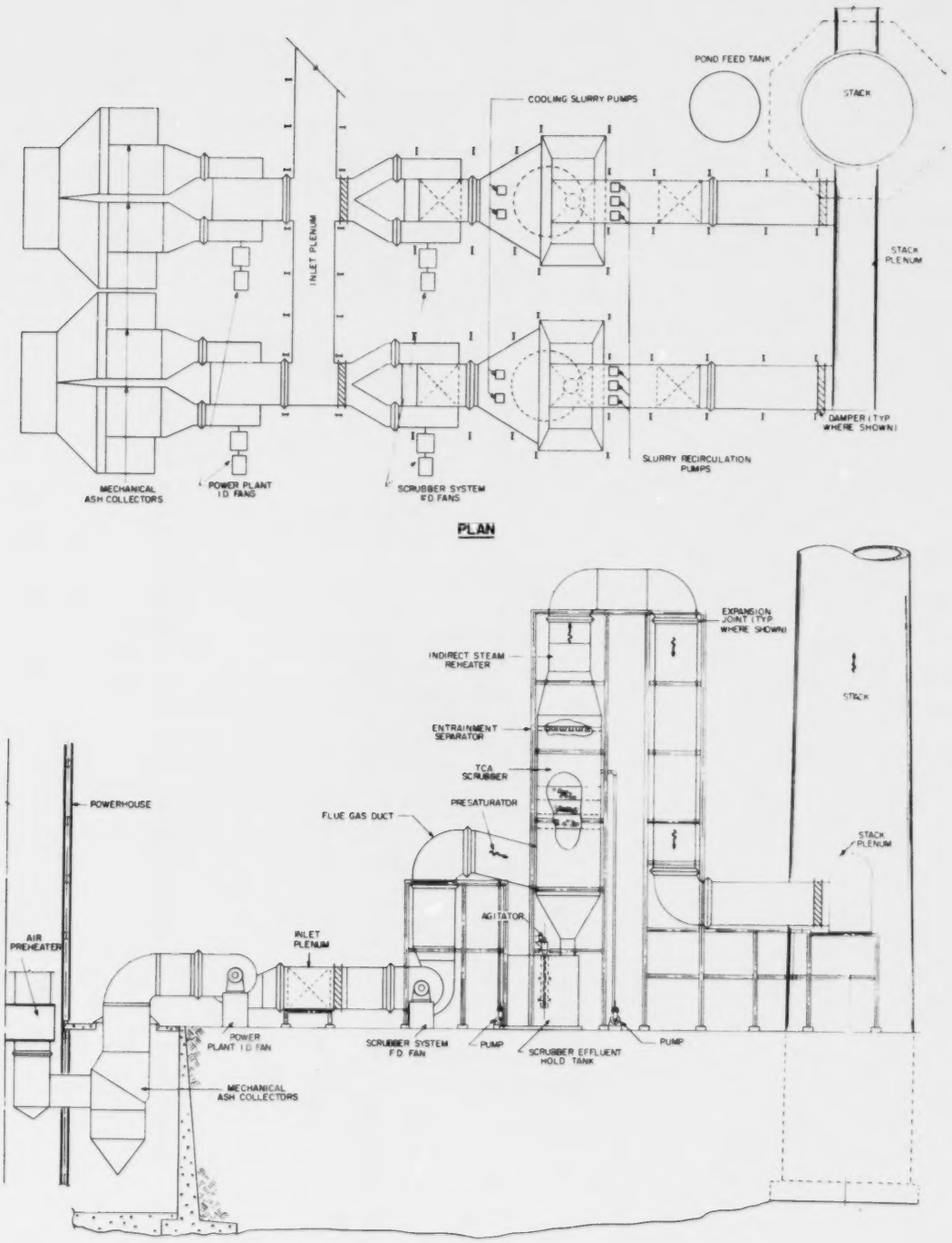
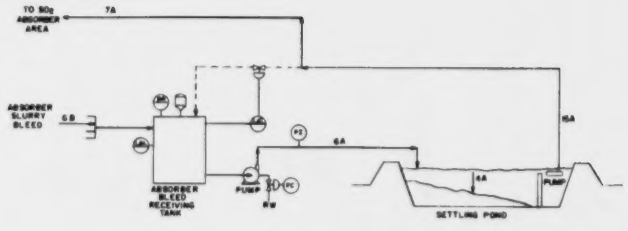
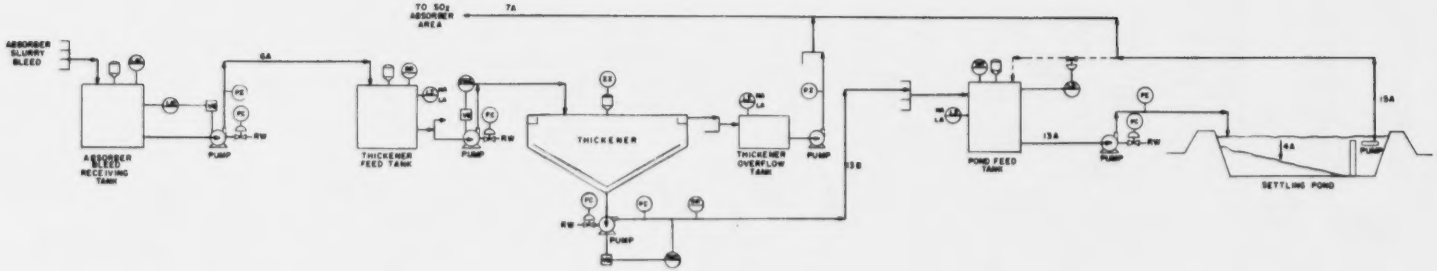


Figure A-3. Plan and elevation for limestone scrubbing area.



Waste Disposal Option 1

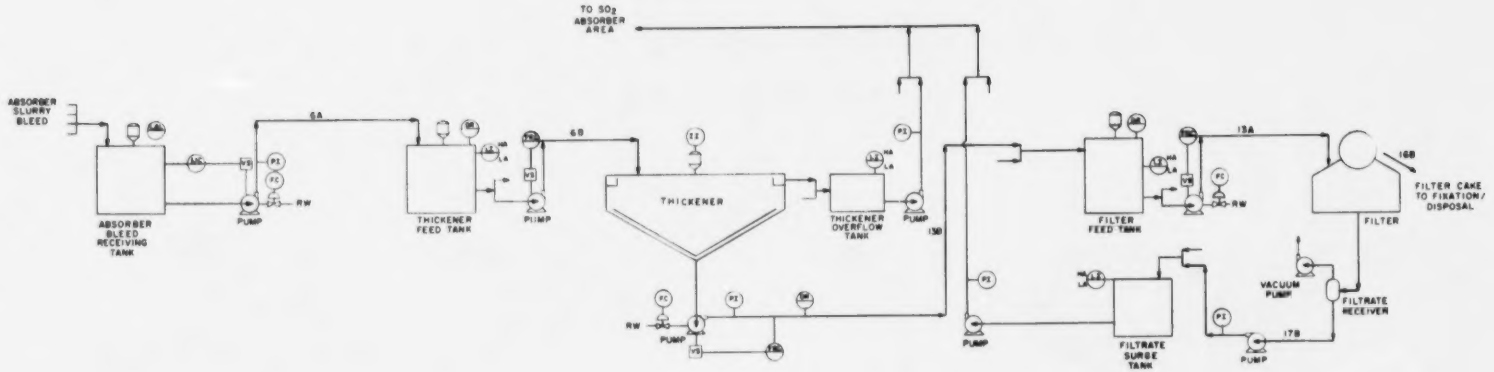
Onsite Ponding



Waste Disposal Option 2

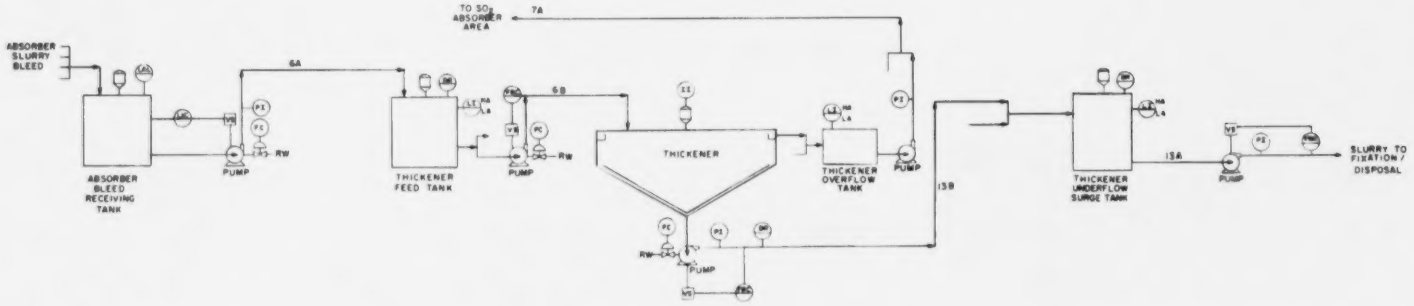
Thickener Ponding

Figure A-4. Waste disposal options 1 and 2.



Waste Disposal Option 4

Thickener-Filter-Fixation



Waste Disposal Option 3

Thickener-Fixation

Figure A-5. Waste disposal options 3 and 4.

APPENDIX B

DETAILED DESCRIPTIONS OF MODEL INPUT VARIABLES

TABLE B-1. MODEL INPUTS - FORTRAN VARIABLE NAMES

Line	
1	XINPUT XBC XALK XSSV XSRHT
2	OUTPUT XHGAS XWGAS XRAIR XRGAS XSRHO XSKGAS XSSO XDIS XSTR XGPM XIT
3	IRPT IEQPR IWTBAL
4	Case identification (up to 72 alphanumeric characters)
5	XESP MW BHR HVC EXSAIR THG XRH TSK TSTEAM HVS
6	WPC WPH WPO WPN WPSUL WPCL WPASH WPH2O SULO ASHO IASH ASHUPS ASHSCR
7	XLG VLG VTR V VRH ISO2 XSO2 TR XSR SRIN XIALK WPMGO XMGOAD WPI WPM ASHCAO ASHMGO
8	WPS PSD RS PSC OX PSF FILRAT PHLIME IVPD VPD DEPTAP
9	ISCRUB XNS XNG HS RAIN SEEPRT EVAPRT WINDEX HPTONW NSPREP NOTRAN NOREDN PCNTRN
10	ISLUDG SDFEE PSAMAX ACRE$ PDEPTH PMXEXC DISTPD ILINER XLINA XLINB
11	ENGIN FLDEXP FEES CONT START CONINT XINT PCTMNT PDMNTP PCTOVR PCTADM UNDCAP PCTINS
12	UC(1) - UC(7) MINDEX LINDEX YRINV YRREV
13	IOPSCH PNDCAP BAGDLP BAGRAT BGCOST BGLIFE EFFPS ESPDLP RESIST SCARAT ICEPYE CHPIOX
14	IYROP — Lines 14-17 are required only if the IOPSCH option is set
15	IA(1) - IA(10) — to 3. Lines 15-17 depend on the value of the IYROP
16	IA(11) - IA(20) — variable; up to 10 entries per line are required, one
17	IA(21) - IA(30) — entry for each of the years 1 - IYROP.
18	END or NEXT

TABLE B-2. MODEL INPUT VARIABLE DEFINITIONS

Line No.	Variable	Definition	Units or values
1	XINPUT	Option to control the printing of input data variables. If a value of zero is selected, no input data variables are printed; the options to individually control the printing of input variables are ignored.	0 = No input data printed 1 = Print input variables according to individual input print option
1	XBC	Controls the printing of boiler characteristics input variables.	0 = No print 1 = Print
1	XALK	Controls the printing of alkali input variables.	0 = No print 1 = Print
1	XSSV	Controls the printing of scrubber system input variables.	0 = No print 1 = Print
1	XSRHT	Controls the printing of steam reheater input variables.	0 = No print 1 = Print
2	OUTPUT	Option to control the printing of model output. If a value of zero is selected, no output listings are printed and the options to individually control the printing of output listings are ignored.	0 = No output printing 1 = Print output listings according to individual output print option
2	XHGAS	Controls the printing of calculated properties of hot gas to scrubber.	0 = No print 1 = Print
2	XWGAS	Controls the printing of calculated properties of wet gas from scrubber.	0 = No print 1 = Print
2	XRAIR	Controls the printing of calculated properties of reheater air.	0 = No print 1 = Print
2	XRGAS	Controls the printing of calculated properties of reheater gas (oil-fired).	0 = No print 1 = Print
2	XSRHO	Controls the printing of calculated properties of inline steam reheater.	0 = No print 1 = Print
2	XSKGAS	Controls the printing of calculated properties of stack gas.	0 = No print 1 = Print

(continued)

TABLE B-2 (continued)

Line No.	Variable	Definition	Units or values
2	XSSO	Controls the printing of calculated scrubber system parameters.	0 = No print 1 = Print
2	XDIS	Controls the printing of calculated properties of system discharge stream.	0 = No print 1 = Print
2	XSTR	Controls the printing of calculated properties of scrubber system internal streams (excluding sludge discharge and makeup water). This option does not affect the printout of total stream flow rate.	0 = No print 1 = Print
2	XGPM	Controls printing of total flow rates (gpm and lb/hr) of internal streams (excluding sludge discharge and makeup water).	0 = No print 1 = Print
2	XIT	For the interactive calculation of stoichiometry, this option controls the printing of the iteration number and of the current and the preceding stoichiometry values.	0 = No print 1 = Print
3	IRPT	Option to select either a short-form printout (totals only) or a long-form printout.	0 = Short print 1 = Long print
3	IEQPR	Controls the printing of the equipment list.	0 = No print 1 = Print
3	IWTBAL	Controls the printing of calculated properties of water balance.	0 = No print 1 = Print
4	CASEID	Case identification - this field is free form and may be up to 72 characters in length.	0 = No print 1 = Print
5	XESP	Particulate collection option No mechanical collector available Mechanical collector available Particulate version	 0 1 2
5	MW	Electric power output	Megawatts
5	BHR	Boiler heat rate	Btu/kWh
5	HVC	Heating value of coal	Btu/lb
5	EXSAIR	Excess air	Percent
5	THG	Temperature of hot gas to scrubber	^{o}F

(continued)

TABLE B-2 (continued)

Line No.	Variable	Definition	Units or values
5	XRH	Reheat option Inline steam reheater (XRH value = 2) is the only type of reheat available at this time.	
5	TSK	Temperature of stack gas	^{o}F
5	TSTEAM	Temperature of reheater steam	^{o}F
5	HVS	Heat of vaporization of reheater steam	Btu/lb
6	WPC WPH WPO WPN WPSUL WPCL WPASH WPH2O	Amount of component (C, H, O, N, S, Cl, ash, H_2O) in coal	Weight percent
6	SULO	Sulfur to overhead as SO_2 gas (remainder goes to bottom ash).	Weight percent
6	ASHO	Ash to overhead as particulates (remainder goes to bottom ash).	Weight percent
6	IASH	Unit of measure option for particulate removal Default to model assumptions — 0 Percent removal — 1 Pounds particulates — 2 Upstream removal (percent) with scrubber default — 3 (The actual values for particulate removal are provided by the ASHUPS and ASHSCR variables that immediately follow.)	
6	ASHUPS	Value for particulate removal upstream from scrubber (Unit of measure is indicated by the IASH option above.)	
6	ASHSCR	Value for particulate removal within scrubber (Unit of measure is indicated by the IASH option above.)	
7	XLG	L/G ratio in scrubber (Refer to the XSR option on the following page.)	Gal/kft^3
7	VLG	L/G ratio in venturi	Gal/kft^3

(continued)

TABLE B-2 (continued)

Line No.	Variable	Definition	Units or values
7	VTR	Venturi hold tank residence time	Minute
7	V	Scrubber gas velocity (superficial)	Ft/sec
7	VRH	Superficial gas velocity through reheater (face velocity)	Ft/sec
7	ISO2	Unit of measure option for SO_2 removal	
		SO_2 to be removed is a percent value	1
		SO_2 emission concentration is a pounds SO_2/MBtu value; SO_2 emission concentration is a ppm value (The acutal value of the SO_2 to be removed is provided by the XSO2 variable that immediately follows.)	2 3
7	XSO2	Value for SO_2 to be removed. (Unit of measure is indicated by the ISO2 option above; refer to the XSR option below for additional requirements.)	
7	TR	EHT residence time	Minute
7	XSR	Stoichiometry, L/G in scrubber, and SO_2 removal option. This option controls model processing of the stoichiometry value, SRIN, below; the L/G ratio in the scrubber, XLG, on the preceding page; and the SO_2 to be removed, XSO2, above (if XSO2 is required then ISO2 is also required).	
		SRIN, XLG, and XSO2 (also ISO2) will be processed as input variables.	0
		XLG and XSO2 (also ISO2) will be processed as input variables and SRIN will be calculated by the model.	1
		SRIN and XSO2 (also ISO2) will be processed as input variables and XLG will be calculated by the model.	2
		SRIN and XLG will be processed as input variables and XSO2 will be calculated by the model (all three units of measure will be provided by the calculated results).	3

(continued)

TABLE B-2 (continued)

Line No.	Variable	Definition	Units or values
7	SRIN	Value for stoichiometry (refer to the XSR option above).	Moles $CaCO_3$ added as limestone per mole SO_2 absorbed
7	XIALK	Alkali addition option Limestone Lime	 1 2
7	WPMGO	Soluble MgO in limestone-lime additive	Weight percent dry basis
7	XMGOAD	Soluble MgO added to system (separate from limestone-lime addition)	Pound soluble MgO/ 100 pound limestone
7	WPI	Insolubles in limestone-lime additive	Weight percent dry basis
7	WPM	Moisture in limestone-lime additive	Lb/100 pound dry additive
7	ASHCAO	Soluble CaO in particulates	Weight percent
7	ASHMGO	Soluble MgO in particulates	Weight percent
8	WPS	Solids in recycle slurry to scrubber	Weight percent
8	PSD	Solids in sludge discharge	Weight percent
8	RS	Clarifier solids settling rate	Ft/hr
8	PSC	Percent solids in clarifier underflow	Weight percent
8	OX	Oxidation of sulfite in scrubber system	Mole percent
8	PSF	Percent solids in filter cake	Percent
8	FILRAT	Filtration rate	Tons/ft^2/day
8	PHLIME	Recirculation liquor pH for lime system (value is ignored for limestone system).	
8	IVPD	Venturi ΔP option ΔP is input in inches H_2O Throat velocity (ft/sec) is input and the corresponding VPD is calculated by corresponding	 0 1
8	VPD	Value for either ΔP or throat velocity indicated inches H_2O by the IVPD option above	

(continued)

TABLE B-2 (continued)

Line No.	Variable	Definition	Units or values
8	DELTAP	Override ΔP for entire system	Inch H_2O
9	ISCRUB	TCA scrubbing option. TCA scrubbing (ISCRUB value = 2) is the only type of scrubbing available in the model at this time.	
9	XNS	Number of TCA stages	
9	XNG	Number of TCA grids	
9	HS	Height of spheres per stage	Inch
9	RAIN	Annual rainfall	In./yr
9	SEEPRT	Seepage rate	Cm/sec
9	EVAPRT	Annual evaporation	In./yr
9	WINDEX	Limestone hardness work index factor value 5-15.	Wi
9	HPTONW	Fineness of grind index factor (see Table B-3)	hp/(ton) (wi)
9	NSPREP	Number of redundant preparation units	(0-9)
9	NOTRAN	Number of operating scrubber trains	
9	NOREDN	Number of redundant scrubber trains	
9	PCNTRN	Entrainment level as percentage of wet gas from scrubber	Weight percent
10	ISLUDG	Sludge option Onsite ponding Thickener - ponding Thickener - fixation (fee) Thickener - filter - fixation (fee) (For ISLUDG = 3 or 4, the SDFEE variable immediately below must be provided.)	 1 2 3 4
10	SDFEE	Sludge disposal fee. (Either an actual value or a zero value must be provided; refer to the ISLUDG option above.)	$/ton dry sludge
10	PSAMAX	Total available land for construction of pond	Acres

(continued)

TABLE B-2 (continued)

Line No.	Variable	Definition	Units or values
10	ACRE$	Land cost	$/acre
10	PDEPTH	Final depth of sludge in pond (ignored in pond optimization model).	Feet
10	PMXEXC	Maximum excavation depth	Feet
10	DISTPD	Distance from scrubber area to pond	Feet
10	ILINER	Pond lining option Clay liner Synthetic liner No liner (Refer to the XLINA and XLINB variables that immediately follow.)	 1 2 3
10	XLINA	If ILINER = 1, XLINA = clay depth If ILINER = 2, XLINA = material unit cost If ILINER = 3, XLINA = 0	Inch $/yd^2
10	XLINB	If ILINER = 1, XLINB = clay cost If ILINER = 2, XLINB = labor unit cost If ILINER = 3, XLINB = 0	$/yd^3 $/yd^2
11	ENGIN	Engineering design and supervision	Percent
11	FLDEXP	Construction expenses	Percent
11	FEES	Contractor fees	Percent
11	CONT	Contingency	Percent
		Indirect investment cost factors as percent of subtotal fixed investment (See Tables B-4 and B-5)	
11	START	Allowance for startup and modifications	Percent
11	CONINT	Interest during construction	Percent
11	XINT	Cost of capital (See Table B-6)	Percent
11	PCTMNT	Maintenance rate, applied as percent of direct investment excluding pond cost (See Table B-7)	Percent
11	PDMNTP	Pond maintenance rate, applied as percent of direct pond investment (See Table B-7)	Percent

(continued)

TABLE B-2 (continued)

Line No.	Variable	Description	Units or values
11	PCTOVR	Plant overhead rate, applied as percent of conversion costs less utilities	Percent
11	PCTADM	Administrative research and service overhead rate, applied as percent of operating labor and supervision	Percent
11	UNDCAP	Annual capital charge basis for undepreciated investment (See Table B-6)	Percent
11	PCTINS	Insurance and interim replacement as percent of TCI total capital investment	Percent
12	UC (1)	Limestone unit cost	$/ton
12	UC (2)	Lime unit cost	$/ton
12	UC (3)	Operating labor and supervision unit cost	$/man-hr
12	UC (4)	Steam unit cost	$/klb
12	UC (5)	Process water unit cost	$/kgal
12	UC (6)	Electricity unit cost	$/kWh
12	UC (7)	Analyses unit cost	$/hr
12	MINDEX	Chemical Engineering material cost index (See Table B-8)	
12	LINDEX	Chemical Engineering labor cost index (See Table B-8)	
12	YRINV	Investment year cost basis	Year
12	YRREV	Revenue requirement year cost basis	Year
13	IOPSCH	Operating profile option TVA profile FERC profile Input profile (Refer to the IYROP and IA(n) options on the following page.)	 1 2 3
13	PNDCAP	Expected pond capacity (controls pond design capacity; if 100% of sludge is to be ponded over the life of the unit, input 1.0; if 80% of sludge is to be ponded, input 0.80.)	

(continued)

TABLE B-2 (continued)

Line No.	Variable	Definition	Units or values
13	BAGDLP	Baghouse pressure drop	Inches H_2O
13	BAGRAT	Baghouse ratio (typically = 0.8)	$\frac{\text{Open ft}^2}{\text{Actual ft}^2}$
13	BGCOST	Bag cost	$\$/ft^2$
13	BGLIFE	Bag life	Year
13	EFFPS	ESP rectification efficiency	Percent
13	ESPDLP	ESP pressure drop	Inches H_2O
13	RESIST	Resistivity option (high or low)[a] Assume ω = 20 ft/min Assume ω = 30	 1 2
13	SCARAT	SCA ratio Contingency or safety factor (fractional) to apply to calculated collected area	
13	ICEPYE	Chemical Engineering plant index year	Year
13	CHPIOX	Chemical Engineering plant index (See Table B-8)	
14	IYROP	Years remaining life (lines 14 through 17 are needed only if the IOPSCH variable on the preceding page is set to 3).	
15	IA(1) - IA(10)	Operating hr/yr (input only 10 years per line)	
16	IA(11) - IA(20)	Operating hr/yr (input only 10 years per line)	
17	IA(21) - IA(30)	Operating hr/yr (input only 10 years per line)	
18	END or NEXT	"END" terminates further execution. "NEXT" execution will continue with the next group of input variables. (If variable IYROP is not equal to 3, line 14 will be the "END" or "NEXT" line.)	

a. Required for sizing hot ESP. Drift velocity (w) is related to percent sulfur in the cold ESP model, but is an input for the hot ESP model.

TABLE B-3. LIMESTONE FINENESS OF GRIND INDEX FACTOR

Ground limestone product size distribution			Index factor (HPTONW)	
80%-micron	% -200 mesh	% -325 mesh	HP required (ton) (wi)	
129	60		1.11	
113	65		1.22	
98	70		1.35	
85	75		1.51	
74	80		1.72	
62	85		2.04	
58	86	70	2.19	
51	90	75	2.54	Base
44	93	80	3.04	
40	95		3.40	
37		85	3.64	
31		90	4.44	
24		95	5.70	

Data from KVS Rock Talk Manual, Kennedy Van Saun Corporation, Danville, Pennsylvania, 1974.

TABLE B-4. INDIRECT INVESTMENT AND ALLOWANCE COST FACTORS

Power unit size	Cost factor, percentage of direct investment		
	200 MW	500 MW	1000 MW
Engineering design and supervision	11	9	8
Construction expenses	18	16	15
Contractor	7	5	5
Contingency	11	10	9

	Cost factor, percentage of subtotal fixed investment		
Allowance for startup and modifications	8	8	8
Interest during construction	12	12	12

TABLE B-5. INTEREST DURING CONSTRUCTION

Example 1 - 10% simple interest rate, 60:40 debt[a]-equity ratio

	Year			
	1	2	3	Total
Fraction of total expenditure as borrowed funds	0.15	0.30	0.15	0.60
Simple interest at 10%/yr as percent of total expenditure				
Year 1 debt	1.5	1.5	1.5	4.5
Year 2 debt	-	3.0	3.0	6.0
Year 3 debt	-	-	1.5	1.5
Accumulated interest as percent of total expenditure	1.5	4.5	6.0	12.0

Example 2 - 8% simple interest rate, 50:50 debt-equity ratio

	Year			
	1	2	3	Total
Fraction of total expenditure as borrowed funds	0.125	0.250	0.125	0.50
Simple interest at 8%/yr as percent of total expenditure				
Year 1 debt	1.0	1.0	1.0	3.0
Year 2 debt	-	2.0	2.0	4.0
Year 3 debt	-	-	1.0	1.0
Accumulated interest as percent of total expenditure	1.0	3.0	4.0	8.0

a. Interest during construction is estimated as a percent of subtotal fixed investment considering (1) simple interest rate, (2) debt-equity ratio, and (3) project construction and expenditure schedule. Examples illustrate interest during construction for two projects with 3-yr construction schedules but different simple interest rates and debt-equity ratios.

TABLE B-6. ANNUAL CAPITAL CHARGES FOR POWER INDUSTRY FINANCING

	Percentage of total depreciable capital investment
	30-yr remaining life
Depreciation-straight line (based on years remaining life of power unit)	3.3
Interim replacements (equipment having less than 30-yr life)	0.7
Insurance	0.5
Property taxes	1.5
Total rate applied to original investment	6.0

	Percentage of unrecovered capital investment[a]	
	60:40 debt-equity ratio; 10% interest-on bonds, 14% return on equity	50:50 debt-equity ratio; 8% interest-on bonds, 12% return on equity
Cost of capital (capital structure)		
Bonds	6.0	4.0
Equity[b]	5.6	6.0
Income taxes (Federal and State)[c]	5.6	6.0
Total rate applied to depreciation base[d]	17.2	16.0

a. Original investment yet to be recovered or "written off."
b. Contains retained earnings and dividends.
c. Since income taxes are approximately 50% of gross return, the amount of taxes is the same as the return on equity.
d. Overall cost of capital (XINT) = return on bonds + return on equity.

TABLE B-7. MAINTENANCE RATE GUIDELINE

Power unit size	200 MW	500 MW	1000 MW
Plant maintenance (PCTMNT)[a]	9	8	7
Pond maintenance (PDMNTP)[b]			
Unlined pond	3	3	3
Clay-lined pond	3	3	3
Synthetic-lined pond	-	-	-

a. Percent of direct investment excluding pond construction costs.
b. Percent of pond construction cost.

TABLE B-8. COST INDEXES AND PROJECTIONS

Year	1974	1975	1976	1977	1978[a]	1979[a]	1980[a]	1981[a]	1982[a]	1983[a]
Plant	165.4	182.4	192.1	204.1	221.4	240.2	259.4	278.9	299.8	322.3
Material[b]	171.2	194.7	205.8	220.9	240.8	262.5	286.1	309.0	333.7	360.4
Labor[c]	163.3	168.6	174.2	178.2	194.2	209.7	226.5	244.6	264.2	285.3

a. Projections.
b. Same as index in Chemical Engineering for "equipment, machinery, supports."
c. Same as index in Chemical Engineering for "construction labor."

APPENDIX C

BASE CASE INPUT AND PRINTOUT

TABLE C-1

Line No.	BASE CASE INPUT DATA SET
1	1, 1, 1, 1, 1
2	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
3	1, 1, 1
4	BASE CASE EXAMPLE 500 MW
5	2, 500, 9000, 10500, 33, 300, 2, 175, 470, 751
6	57.56, 4.14, 7.00, 1.29, 3.12, .1, 16.0, 10.74, 95, 80, 1, 98.5, 50
7	55, 0, 0, 12.5, 25, 1, 85, 12, 1, 0.0, 1, 0, 0, 2.85, 5, 0, 0
8	15, 40, .2, 40, 30, 65, 1.2, 7.0, 0, 12, 20
9	2, 3, 4, 5, 35, .0000001, 30, 10, 1.35, 1, 4, 1, .1
10	1, 0, 500, 3500, 25, 25, 5280, 1, 12, 2.5
11	9, 16, 5, 10, 8, 12, 11.6, 8, 3, 50, 10, 17.2, 1.17
12	8, 40, 12, 1.7, .12, .030, 17, 262.5, 209.7, 1979, 1980
13	2, 1, 5, .8, 2.0, 3, 65, 1, 2, 1.10, 1979, 240.2
14	END

TABLE C-2. BASE CASE PRINTOUT

```
BASE CASE EXAMPLE 500 MW                                        CASE 001

                    *** INPUTS ***

BOILER CHARACTERISTICS
------ ---------------

MEGAWATTS =   500.

BOILER HEAT RATE =  9000. BTU/KWH

EXCESS AIR =  33. PERCENT, INCLUDING LEAKAGE

HOT GAS TEMPERATURE = 300. DEG F

COAL ANALYSIS, WT % AS FIRED :

  C      H      O      N      S      CL     ASH    H2O
57.56   4.14   7.00   1.29   3.12   0.10  16.00  10.74

SULFUR OVERHEAD =  95.0 PERCENT

ASH OVERHEAD =  80.0 PERCENT

HEATING VALUE OF COAL = 10500. BTU/LB

                          EFFICIENCY,     EMISSION,
FLYASH REMOVAL                 %         LBS/M BTU
------ -------           ----------      ---------

UPSTREAM OF SCRUBBER          98.5            0.18

WITHIN SCRUBBER               50.0            0.09

ALKALI
------

LIMESTONE :

      CACO3        =  97.15 WT % DRY BASIS
      SOLUBLE MGO  =   0.0
      INERTS       =   2.85
      MOISTURE CONTENT =   5.00 LB H2O/100 LBS DRY LIMESTONE
      LIMESTONE HARDNESS WORK INDEX FACTOR = 10.00
      LIMESTONE DEGREE OF GRIND FACTOR =  1.35

FLY ASH :

      SOLUBLE CAO  =   0.0  WT %
      SOLUBLE MGO  =   0.0
      INERTS       = 100.00


RAW MATERIAL HANDLING AREA
--- -------- -------- ----

NUMBER OF REDUNDANT ALKALI PREPARATION UNITS =    1
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(continued)

TABLE C-2 (continued)

SCRUBBER SYSTEM VARIABLES

NUMBER OF OPERATING SCRUBBING TRAINS = 4

NUMBER OF REDUNDANT SCRUBBING TRAINS = 1

NUMBER OF BEDS = 3

NUMBER OF GRIDS = 4

HEIGHT OF SPHERES PER BED = 5.0 INCHES

LIQUID-TO-GAS RATIO = 55. GAL/1000 ACF

SCRUBBER GAS VELOCITY = 12.5 FT/SEC

SO2 REMOVAL = 85. PERCENT

STOICHIOMETRY RATIO TO BE CALCULATED

ENTRAINMENT LEVEL = 0.10 WT %

EHT RESIDENCE TIME = 12.0 MIN

SO2 OXIDIZED IN SYSTEM = 30.0 PERCENT

SOLIDS IN RECIRCULATED SLURRY = 15.0 WT %

SOLIDS DISPOSAL SYSTEM

COST OF LAND = 3500.00 DOLLARS/ACRE

SOLIDS IN SYSTEM SLUDGE DISCHARGE = 40.0 WT %

MAXIMUM POND AREA = 500. ACRES

MAXIMUM EXCAVATION = 25.00 FT

DISTANCE TO POND = 5280. FT

POND LINED WITH 12.0 INCHES CLAY

STEAM REHEATER (IN-LINE)

SATURATED STEAM TEMPERATURE = 470. DEG F

HEAT OF VAPORIZATION OF STEAM = 751. BTU/LB

OUTLET FLUE GAS TEMPERATURE = 175. DEG F

SUPERFICIAL GAS VELOCITY (FACE VELOCITY) = 25.0 FT/SEC

IT	SR	SROLD
1	1.41	1.50
2	1.41	1.41

(continued)

TABLE C-2 (continued)

FLUE GAS TO STACK

	MOLE PERCENT	LB-MOLE/HR	LB/HR
CO2	11.675	0.2089E+05	0.9193E+06
SO2	0.033	0.5943E+02	0.3807E+04
O2	4.472	0.8000E+04	0.2560E+06
N2	68.865	0.1232E+06	0.3452E+07
H2O	14.955	0.2676E+05	0.4820E+06

SPECIFIED SO2 REMOVAL EFFICIENCY = 85.0 %

CALCULATED SO2 EMISSION = 0.85 POUNDS PER MILLION BTU

CALCULATED SO2 CONCENTRATION IN STACK GAS = 332. PPM

FLYASH EMISSION = 0.09 LBS/MILLION BTU
= 0.042 GRAINS/SCF (WET) OR 411. LB/HR

STACK GAS FLOW RATE = .1130E+07 SCFM (60 DEG F, 1 ATM)
= .1380E+07 ACFM (175. DEG F, 1 ATM)

STEAM REHEATER (IN-LINE)

SUPERFICIAL GAS VELOCITY (FACE VELOCITY) = 25.0 FT/SEC

SQUARE PIPE PITCH = 2 TIMES ACTUAL PIPE O.D.

SATURATED STEAM TEMPERATURE = 470. DEG F

OUTLET FLUE GAS TEMPERATURE = 175. DEG F

REQUIRED HEAT INPUT TO REHEATER = 0.6882E+08 BTU/HR

STEAM CONSUMPTION = 0.9163E+05 LBS/HR

OUTSIDE PIPE DIAMETER, IN.	PRESSURE DROP, IN. H2O	HEAT TRANSFER COEFFICIENT, BTU/HR FT2 DEG F
1.00	0.76	0.2082E+02

	REHEATER OUTSIDE PIPE AREA, SQ FT PER TRAIN	NUMBER OF PIPES PER BANK PER TRAIN	NUMBER OF BANKS (ROWS) PER TRAIN
INCONEL	0.1284E+04	87	3
CORTEN	0.1313E+04	87	4
TOTAL	0.2597E+04	87	7

(continued)

TABLE C-2 (continued)

WATER BALANCE INPUTS

RAINFALL(IN/YEAR)	35.
POND SEEPAGE(CM/SEC)*10**8	10.
POND EVAPORATION(IN/YEAR)	30.

WATER BALANCE OUTPUTS

WATER AVAILABLE

RAINFALL	562. GPM	281059. LB/HR
ALKALI	5. GPM	2453. LB/HR
TOTAL	567. GPM	283512. LB/HR

WATER REQUIRED

HUMIDIFICATION	428. GPM	214145. LB/HR
ENTRAINMENT	10. GPM	5102. LB/HR
DISPOSAL WATER	187. GPM	93329. LB/HR
HYDRATION WATER	11. GPM	5724. LB/HR
CLARIFIER EVAPORATION	0. GPM	0. LB/HR
POND EVAPORATION	522. GPM	260805. LB/HR
SEEPAGE	20. GPM	9970. LB/HR
TOTAL WATER REQUIRED	1179. GPM	589075. LB/HR
NET WATER REQUIRED	611. GPM	305563. LB/HR

(continued)

TABLE C-2 (continued)

SCRUBBER SYSTEM

TOTAL NUMBER OF SCRUBBING TRAINS (OPERATING+REDUNDANT) = 5

SO2 REMOVAL = 85.0 PERCENT

PARTICULATE REMOVAL IN SCRUBBER SYSTEM = 50.0 PERCENT

TCA PRESSURE DROP ACROSS 3 BEDS = 8.6 IN. H2O

TOTAL SYSTEM PRESSURE DROP = 14.8 IN. H2O

OVERRIDE TOTAL SYSTEM PRESSURE DROP = 20.0 IN. H2O

SPECIFIED LIQUID-TO-GAS-RATIO = 55. GAL/1000 ACF

LIMESTONE ADDITION = 0.4906E+05 LB/HR DRY LIMESTONE

CALCULATED LIMESTONE STOICHIOMETRY = 1.41 MOLE CACO3 ADDED AS LIMESTONE PER MOLE SO2 ABSORBED

SOLUBLE CAO FROM FLY ASH = 0.0 MOLE PER MOLE SO2 ABSORBED

TOTAL SOLUBLE MGO = 0.0 MOLE PER MOLE SO2 ABSORBED

TOTAL STOICHIOMETRY = 1.41 MOLE SOLUBLE (CA+MG) PER MOLE SO2 ABSORBED

SCRUBBER INLET LIQUOR PH = 5.64

MAKE UP WATER = 611. GPM

CROSS-SECTIONAL AREA PER SCRUBBER = 425. SQ FT

SYSTEM SLUDGE DISCHARGE

SPECIES	LB-MOLE/HR	LB/HR	SOLID COMP, WT %	LIQUID COMP, PPM
CASO3 .1/2 H2O	0.2356E+03	0.3042E+05	48.45	
CASO4 .2H2O	0.9996E+02	0.1720E+05	27.41	
CACO3	0.1333E+03	0.1334E+05	21.26	
INSOLUBLES	----------	0.1810E+04	2.88	
H2O	0.5180E+04	0.9333E+05		
CA++	0.7219E+01	0.2893E+03		3073.
MG++	0.0	0.0		0.
SO3--	0.1539E+00	0.1233E+02		131.
SO4--	0.1066E+01	0.1024E+03		1088.
CL-	0.1199E+02	0.4250E+03		4513.

TOTAL DISCHARGE FLOW RATE = 0.1569E+06 LB/HR
= 237. GPM

TOTAL DISSOLVED SOLIDS IN DISCHARGE LIQUID = 8805. PPM

DISCHARGE LIQUID PH = 7.32

(continued)

TABLE C-2 (continued)

SCRUBBER SLURRY BLEED

SPECIES	LB-MOLE/HR	LB/HR
CASO3 .1/2 H2O	0.2356E+03	0.3042E+05
CASO4 .2H2O	0.9996E+02	0.1720E+05
CACO3	0.1333E+03	0.1334E+05
INSOLUBLES	----------	0.1810E+04
H2O	0.1957E+05	0.3526E+06
CA++	0.2727E+02	0.1093E+04
MG++	0.0	0.0
SO3--	0.5816E+00	0.4656E+02
SO4--	0.4028E+01	0.3870E+03
CL-	0.4529E+02	0.1605E+04

TOTAL FLOW RATE = 0.4185E+06 LB/HR
= 760. GPM

TOTAL SUPERNATE RETURN

SPECIES	LB-MOLE/HR	LB/HR
H2O	0.1496E+05	0.2694E+06
CA++	0.2084E+02	0.8353E+03
MG++	0.0	0.0
SO3--	0.4445E+00	0.3558E+02
SO4--	0.3078E+01	0.2957E+03
CL-	0.3461E+02	0.1227E+04

TOTAL FLOW RATE = 0.2718E+06 LB/HR
= 544. GPM

SUPERNATE TO WET BALL MILL

SPECIES	LB-MOLE/HR	LB/HR
H2O	0.1689E+04	0.3044E+05
CA++	0.2354E+01	0.9436E+02
MG++	0.0	0.0
SO3--	0.5021E-01	0.4020E+01
SO4--	0.3478E+00	0.3341E+02
CL-	0.3910E+01	0.1386E+03

TOTAL FLOW RATE = 0.3071E+05 LB/HR
= 61. GPM

(continued)

TABLE C-2 (continued)

LIMESTONE SLURRY FEED

SPECIES	LB-MOLE/HR	LB/HR
CACO3	0.4761E+03	0.4766E+05
SOLUBLE MGO	0.0	0.0
INSOLUBLES	----------	0.1398E+04
H2O	0.1799E+04	0.3242E+05
CA++	0.2508E+01	0.1005E+03
MG++	0.0	0.0
SO3--	0.5348E-01	0.4281E+01
SO4--	0.3704E+00	0.3558E+02
CL-	0.4164E+01	0.1476E+03

TOTAL FLOW RATE = 0.8177E+05 LB/HR
= 103. GPM

SUPERNATE RETURN TO SCRUBBER OR EHT

SPECIES	LB-MOLE/HR	LB/HR
H2O	0.1327E+05	0.2390E+06
CA++	0.1849E+02	0.7409E+03
MG++	0.0	0.0
SO3--	0.3942E+00	0.3156E+02
SO4--	0.2731E+01	0.2623E+03
CL-	0.3070E+02	0.1088E+04

TOTAL FLOW RATE = 0.2411E+06 LB/HR
= 482. GPM

RECYCLE SLURRY TO SCRUBBER

SPECIES	LB-MOLE/HR	LB/HR
CASO3 .1/2 H2O	0.2172E+05	0.2805E+07
CASO4 .2H2O	0.9218E+04	0.1586E+07
CACO3	0.1229E+05	0.1230E+07
INSOLUBLES	----------	0.1669E+06
H2O	0.1805E+07	0.3251E+08
CA++	0.2515E+04	0.1008E+06
MG++	0.0	0.0
SO3--	0.5363E+02	0.4294E+04
SO4--	0.3715E+03	0.3568E+05
CL-	0.4176E+04	0.1480E+06

TOTAL FLOW RATE = 0.3859E+08 LB/HR
= 70087. GPM

(continued)

TABLE C-2 (continued)

FLUE GAS COOLING SLURRY

SPECIES	LB-MOLE/HR	LB/HR
CASO3 .1/2 H2O	0.1580E+04	0.2040E+06
CASO4 .2H2O	0.6704E+03	0.1154E+06
CACO3	0.8940E+03	0.8949E+05
INSOLUBLES	----------	0.1214E+05
H2O	0.1312E+06	0.2365E+07
CA++	0.1829E+03	0.7330E+04
MG++	0.0	0.0
SO3--	0.3900E+01	0.3123E+03
SO4--	0.2702E+02	0.2595E+04
CL-	0.3037E+03	0.1077E+05

TOTAL FLOW RATE = 0.2806E+07 LB/HR
= 5097. GPM

(continued)

TABLE C-2 (continued)

POND DESIGN

OPTIMIZED TO MINIMIZE TOTAL COST PLUS OVERHEAD

POND DIMENSIONS

DEPTH OF POND	21.34	FT
DEPTH OF EXCAVATION	3.14	FT
LENGTH OF PERIMETER	14803.	FT
LENGTH OF DIVIDER	2703.	FT
AREA OF BOTTOM	1366.	THOUSAND YD2
AREA OF INSIDE WALLS	149.	THOUSAND YD2
AREA OF OUTSIDE WALLS	113.	THOUSAND YD2
AREA OF POND	1505.	THOUSAND YD2
AREA OF POND SITE	1677.	THOUSAND YD2
AREA OF POND SITE	346.	ACRES
VOLUME OF EXCAVATION	1526.	THOUSAND YD3
VOLUME OF SLUDGE TO BE DISPOSED OVER LIFE OF PLANT	10269.	THOUSAND YD3
	6365.	ACRE FT

POND COSTS (THOUSANDS OF DOLLARS)

	LABOR	MATERIAL	TOTAL
CLEARING LAND	517.		517.
EXCAVATION	2846.		2846.
DIKE CONSTRUCTION	1034.		1034.
LINING(12. IN. CLAY)	1263.		1263.
SODDING DIKE WALLS	65.	53.	118.
ROAD CONSTRUCTION	9.	19.	27.
POND CONSTRUCTION	5734.	72.	5806.
LAND COST			1213.
POND SITE			7019.
OVERHEAD			3948.
TOTAL			10967.

(continued)

TABLE C-2 (continued)

RAW MATERIAL HANDLING AND PREPARATION

INCLUDING 2 OPERATING AND 1 SPARE PREPARATION UNITS

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
CAR SHAKER AND HOIST	20HP SHAKER 7.5HP HOIST	1	28582.	1866.
CAR PULLER	25HP PULLER, 5HP RETURN	1	49345.	1866.
UNLOADING HOPPER	16FT DIA, 10FT STRAIGHT SIDE HT, CS	1	4180.	7711.
UNLOADING VIBRATING FEEDER	3.5HP	1	12134.	1866.
UNLOADING BELT CONVEYOR	20FT HORIZONTAL, 5HP	1	17527.	0.
UNLOADING INCLINE BELT CONVEYOR	310FT, 50HP	1	60670.	24875.
UNLOADING PIT DUST COLLECTOR	POLYPROPYLENE BAGTYPE, 2200 CFM, 7.5HP	1	5258.	12438.
UNLOADING PIT SUMP PUMP	60GPM, 70FT HEAD, 5HP	1	3371.	746.
STORAGE BELT CONVEYOR	200FT, 5HP	1	57974.	16169.
STORAGE CONVEYOR TRIPPER	30FPM, 1HP	1	13482.	2488.
MOBILE EQUIPMENT	SCRAPPER TRACTOR	1	136171.	0.
RECLAIM HOPPER	7FT WIDE, 4.25FT HT, 2FT WIDE BOTTOM, CS	2	1079.	1741.
RECLAIM VIBRATING FEEDER	3.5HP	2	24268.	3731.
RECLAIM BELT CONVEYOR	200FT, 5HP	1	40447.	8706.
RECLAIM INCLINE BELT CONVEYOR	193FT, 40HP	1	37750.	13930.
RECLAIM PIT DUST COLLECTOR	POLYPROPYLENE BAG TYPE	1	5258.	12438.
RECLAIM PIT SUMP PUMP	60GPM, 70FT HEAD, 5HP	1	3371.	746.
RECLAIM BUCKET ELEVATOR	90FT HIGH, 75HP	1	80894.	1617.
FEED BELT CONVEYOR	60.FT HORIZONTAL 7.5HP	1	20223.	1368.
FEED CONVEYOR TRIPPER	30 FPM, 1HP	1	13482.	2488.
FEED BIN	13FT DIA, 21FT STRAIGHT SIDE HT, COVERED, CS	3	16179.	29851.
BIN WEIGH FEEDER	14FT PULLEY CENTERS, 2HP	3	54603.	3731.
GYRATORY CRUSHERS	75HP	3	199765.	15672.

(continued)

TABLE C-2 (continued)

BALL MILL DUST COLLECTORS	POLYPROPYLENE BAG TYPE 2200 CFM, 7.5HP	3	15774.	37313.
BALL MILL	12.3TPH, 166.HP	3	475996.	43912.
MILLS PRODUCT TANK	5300 GAL 10FT DIA, 10FT HT, FLAKEGLASS LINED CS	3	14561.	22701.
MILLS PRODUCT TANK AGITATOR	10HP	3	24673.	1119.
MILLS PRODUCT TANK SLURRY PUMP	52.GPM, 60FT HEAD, 2.HP, 2 OPERATING AND 1 SPARES	3	7810.	1493.
SLURRY FEED TANK	54506.GAL, 21.0FT DIA, 21.0FT HT, FLAKEGLASS-LINED CS	1	12189.	26122.
SLURRY FEED TANK AGITATOR	47.HP	1	34432.	2541.
SLURRY FEED TANK PUMPS	26.GPM, 60 FT HEAD, 1.HP, 4 OPERATING AND 4 SPARE	8	20063.	3980.
TOTAL EQUIPMENT COST			1451506.	305284.

(continued)

TABLE C-2 (continued)

SCRUBBING

INCLUDING 4 OPERATING AND 1 SPARE SCRUBBING TRAINS

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
MECHANICAL ASH COLLECTOR	33% PARTICULATE REMOVAL	1	424515.	78325.
F.D. FANS	20.0IN H2O, WITH 1615. HP MOTOR AND DRIVE	5	1873839.	113586.
SHELL			812283.	
RUBBER LINING			1199962.	
MIST ELIMINATOR			368717.	
SLURRY HEADER AND NOZZLES			313679.	
GRIDS			471794.	
SPHERES			175683.	
TOTAL TCA SCRUBBER COSTS		5	3342115.	278548.
REHEATERS		5	1046932.	43280.
SOOTBLOWERS		60	404468.	298505.
EFFLUENT HOLD TANK	231287.GAL, 34.0FT DIA, 34.0FT HT, FLAKEGLASS-LINED CS	5	181225.	354208.
EFFLUENT HOLD TANK AGITATOR	63.HP	5	345851.	127622.
COOLING SPRAY PUMPS	1274.GPM 100FT HEAD, 59.HP, 4 OPERATING AND 6 SPARE	10	117520.	17352.
ABSORBER RECYCLE PUMPS	8761.GPM, 100FT HEAD, 406.HP, 8 OPERATING AND 7 SPARE	15	658657.	51730.
MAKEUP WATER PUMPS	2549.GPM, 200.FT HEAD, 215.HP, 1 OPERATING AND 1 SPARE	2	19790.	1826.
TOTAL EQUIPMENT COST			8414911.	1364980.

(continued)

TABLE C-2 (continued)

WASTE DISPOSAL

ITEM	DESCRIPTION	NO.	MATERIAL	LABOR
ABSORBER BLEED RECEIVING TANK	57760.GAL, 17.0FT DIA, 34.0FT HT, FLAKGLASS-LINED CS	1	14579.	31228.
ABSORBER BLEED TANK AGITATOR	36.HP	1	20467.	1511.
POND FEED SLURRY PUMPS	760.GPM, 130.FT HEAD 46.HP, 1 OPERATING AND 1 SPARE	2	14772.	2887.
POND SUPERNATE PUMPS	544.GPM, 192.FT HEAD, 44.HP, 1 OPERATING AND 1 SPARE	2	8512.	785.
TOTAL EQUIPMENT COST			58331.	36411.

(continued)

TABLE C-2 (continued)

LIMESTONE SLURRY PROCESS -- BASIS: 500 MW UNIT, 1980 STARTUP

PROJECTED CAPITAL INVESTMENT REQUIREMENTS - BASE CASE EXAMPLE 500 MW

CASE 001

	INVESTMENT, THOUSANDS OF 1979 DOLLARS				DISTRIBUTION
	RAW MATERIAL HANDLING AND PREPARATION	SCRUBBING	WASTE DISPOSAL	TOTAL	PERCENT OF DIRECT INVESTMENT
EQUIPMENT					
MATERIAL	1452.	7990.	58.	9500.	30.1
LABOR	305.	1287.	36.	1628.	5.2
PIPING					
MATERIAL	232.	2529.	936.	3698.	11.7
LABOR	93.	741.	341.	1176.	3.7
DUCTWORK					
MATERIAL	0.	1982.	0.	1982.	6.3
LABOR	0.	1349.	0.	1349.	4.3
FOUNDATIONS					
MATERIAL	126.	92.	12.	229.	0.7
LABOR	525.	276.	36.	836.	2.7
POND CONSTRUCTION	0.	0.	5806.	5806.	18.4
STRUCTURAL					
MATERIAL	270.	171.	1.	442.	1.4
LABOR	100.	380.	6.	486.	1.5
ELECTRICAL					
MATERIAL	172.	542.	100.	814.	2.6
LABOR	342.	875.	226.	1443.	4.6
INSTRUMENTATION					
MATERIAL	105.	743.	8.	856.	2.7
LABOR	24.	122.	3.	148.	0.5
BUILDINGS					
MATERIAL	36.	0.	0.	36.	0.1
LABOR	57.	0.	0.	57.	0.2
SERVICES AND MISCELLANEOUS	130.	646.	256.	1032.	3.3
SUBTOTAL DIRECT INVESTMENT	3969.	19725.	7826.	31520.	100.0
ENGINEERING DESIGN AND SUPERVISION	357.	1775.	704.	2837.	9.0
CONSTRUCTION EXPENSES	635.	3156.	1252.	5043.	16.0
CONTRACTOR FEES	198.	986.	391.	1576.	5.0
CONTINGENCY	397.	1972.	783.	3152.	10.0
SUBTOTAL FIXED INVESTMENT	5557.	27615.	10956.	44128.	140.0
ALLOWANCE FOR STARTUP AND MODIFICATIONS	445.	2209.	877.	3530.	11.2
INTEREST DURING CONSTRUCTION	667.	3314.	1315.	5295.	16.8
SUBTOTAL CAPITAL INVESTMENT	6669.	33138.	13148.	52954.	168.0
LAND	7.	3.	1221.	1231.	3.9
WORKING CAPITAL	150.	744.	295.	1189.	3.8
TOTAL CAPITAL INVESTMENT	6826.	33884.	14664.	55374.	175.7

(continued)

TABLE C-2 (continued)

BASE CASE EXAMPLE 500 MW

CASE 001

PARTICULATE REMOVAL INVESTMENT AND OPERATING COST

WPSUL CONTENT (%):	3.12	PARTICULATE EMISSION REGULATION (LB ASH/MILLION BTU):	0.18
ASH CONTENT (%):	16.00	FLUE GAS TEMPERATURE (COLD) (F):	300.0
BTU RATING:	10500	FLUE GAS TEMPERATURE (HOT) (F):	700.0
BOILER TYPE:	DRY PULVERIZED COAL	COST OF ELECTRICITY ($/KWHR):	0.03
NO. OF SCRUBBERS:	4	COST OF STEAM ($/THOUSAND LB):	1.70
SCRUBBER VELOCITY (FT/M):	207.0	FIRST YEAR CAPITAL CHARGE FACTOR:	0.217
PLANT SIZE (MW):	500	BAGHOUSE RATIO (OPER. SQ.FT./ACTUAL SQ.FT.):	0.80
OPERATING HRS/YR:	4512	BAG COST ($/SQ.FT.):	2.00
PUMPING RATE (GAL/1000 ACF):	0.0	BAG LIFE(YEARS):	3.00
SCA RATIO: (ACTUAL SQ.FT./CALC. SQ.FT.)	1.100	FLUE GAS REHEAT TEMPERATURE (F):	175.
		CHEMICAL ENGINEERING PLANT INDEX:	240.2

	ELECTROSTATIC PRECIPITATORS			
	COLD	HOT	BAGHOUSE FABRIC FILTERS	SCRUBBERS
REQUIRED REMOVAL EFFICIENCY (%):	98.50	98.50	98.50	98.50
DRIFT VELOCITY (FT/M):	25.78	30.00		
SPECIFIC COLLECTION AREA (SQ.FT./ACFM):	179.17	153.99		
COLLECTION AREA (SQ.FT.):	275903.4	361921.9	571527.0	
TOTAL CORONA POWER (KW):	3.4	5.2		
AUXILIARY POWER (KW):	226.4	305.9	461.5	
FAN POWER (KW):	241.0	367.8	1204.9	2633.2
PUMP POWER (KW):				0.0
TOTAL POWER (KW):	470.8	678.9	1666.3	2633.2
OPERATING AIR/CLOTH RATIO:			3.4	
INSTALLED AIR/CLOTH RATIO:			2.7	
REQUIRED PRESSURE DROP (INCHES):	1.0	1.0	5.0	10.9
DIAMETER (FEET):				55
REQUIRED REHEAT (BTU/HR):				50660416.0
STEAM SUPPLY/YR (THOUSAND LB):				294084.2
INSTALLED COST (1979 DOLLARS):	$ 3724887	$ 4594420	$ 10459268	$ 19090432
FIRST YEAR CAPITALIZED COST:	$ 808425	$ 997142	$ 2270009	$ 4143259
ANNUAL POWER COST:	$ 63731	$ 91902	$ 225557	$ 356428
ANNUAL OPERATING AND MAINTENANCE COST (1979 DOLLARS):	$ 76227	$ 88642	$ 66150	$ 908024
REPLACEMENT COST (1979 DOLLARS):			$ 453072	
ANNUAL REHEAT COST:				$ 499943
TOTAL ANNUAL COST:	$ 948383	$ 1177686	$ 3012788	$ 5907654
ANNUALIZED COST OF POWER(MILLS/KWHR):	0.42	0.52	1.34	2.62

(continued)

TABLE C-2 (continued)

LIMESTONE SLURRY PROCESS -- BASIS: 500 MW UNIT, 1980 STARTUP

PROJECTED REVENUE REQUIREMENTS - BASE CASE EXAMPLE 500 MW CASE 001

DISPLAY SHEET FOR YEAR= 1
ANNUAL OPERATION KW-HR/KW = 4512

31.39 TONS PER HOUR DRY SLUDGE
TOTAL FIXED INVESTMENT 55373000

	ANNUAL QUANTITY	UNIT COSTS	TOTAL ANNUAL COSTS
DIRECT COSTS			
RAW MATERIAL			
LIMESTONE	110.7 K TONS	8.00/TON	885400
LIME	0.0 K TONS	40.00/TON	0
SUBTOTAL RAW MATERIAL			885400
CONVERSION COSTS			
OPERATING LABOR AND SUPERVISION	20860.0 MAN-HR	12.00/MAN-HR	250400
UTILITIES			
STEAM	413440.0 K LB	1.70/K LB	702900
PROCESS WATER	165510.0 K GAL	0.12/K GAL	19900
ELECTRICITY	38819120.0 KWH	0.030/KWH	1164600
MAINTENANCE			
LABOR AND MATERIAL			1714400
ANALYSES	2420.0 HR	17.00/HR	61200
SUBTOTAL CONVERSION COSTS			3893400
SUBTOTAL DIRECT COSTS			4778800
INDIRECT COSTS			
DEPRECIATION			1765100
COST OF CAPITAL AND TAXES, 17.20% OF UNDEPRECIATED INVESTMENT			9524300
INSURANCE & INTERIM REPLACEMENTS, 1.17% OF TOTAL CAPITAL INVESTMENT			647900
OVERHEAD			
PLANT, 50.0% OF CONVERSION COSTS LESS UTILITIES			1003000
ADMINISTRATIVE, RESEARCH, AND SERVICE, 10.0% OF OPERATING LABOR AND SUPERVISION			25000
SUBTOTAL INDIRECT COSTS			12965300
TOTAL ANNUAL REVENUE REQUIREMENT			17744100
EQUIVALENT UNIT REVENUE REQUIREMENT, MILLS/KWH			7.87

HEAT RATE 9000. BTU/KWH - HEAT VALUE OF COAL 10500 BTU/LB - COAL RATE 966900 TONS/YR

(continued)

TABLE C-2 (continued)

LIMESTONE SLURRY PROCESS -- BASIS: 500 MW UNIT, 1980 STARTUP

PROJECTED LIFETIME REVENUE REQUIREMENTS - BASE CASE EXAMPLE 500 MW

CASE 001

TOTAL CAPITAL INVESTMENT: $ 55374000

YEARS AFTER UNIT START	ANNUAL OPERATION, KW-HR /KW	POWER UNIT HEAT REQUIREMENT, MILLION BTU /YEAR	POWER UNIT FUEL CONSUMPTION, TONS COAL /YEAR	SULFUR REMOVED BY POLLUTION CONTROL PROCESS, TONS/YEAR	BYPRODUCT RATE, EQUIVALENT TONS/YEAR DRY SLUDGE	SLUDGE FIXATION FEE $/TON DRY SLUDGE	ADJUSTED GROSS ANNUAL REVENUE REQUIREMENT EXCLUDING SLUDGE FIXATION COST, $/YEAR	TOTAL ANNUAL SLUDGE FIXATION COST, $/YEAR	NET ANNUAL INCREASE IN TOTAL REVENUE REQUIREMENT, $	CUMULATIVE NET INCREASE IN TOTAL REVENUE REQUIREMENT, $
1	4512	20304000	966900	24300	141600	0.0	17744100	0	17744100	17744100
2	4643	20893500	994900	25000	145700	0.0	17573100	0	17573100	35317200
3	4775	21487500	1023200	25800	149900	0.0	17402600	0	17402600	52719800
4	4906	22077000	1051300	26500	154000	0.0	17230600	0	17230600	69950400
5	5037	22666500	1079400	27200	158100	0.0	17057800	0	17057800	87008200
6	5169	23260500	1107600	27900	162200	0.0	16885600	0	16885600	103893800
7	5300	23850000	1135700	28600	166300	0.0	16711800	0	16711800	120605600
8	5432	24444000	1164000	29300	170500	0.0	16538800	0	16538800	137144400
9	5563	25033500	1192100	30000	174600	0.0	16364100	0	16364100	153508500
10	5694	25623000	1220100	30700	178700	0.0	16189100	0	16189100	169697600
11	5695	25627500	1220400	30700	178700	0.0	15886300	0	15886300	185583900
12	5695	25627500	1220400	30700	178700	0.0	15582700	0	15582700	201166600
13	5695	25627500	1220400	30700	178700	0.0	15279100	0	15279100	216445700
14	5695	25627500	1220400	30700	178700	0.0	14975500	0	14975500	231421200
15	5695	25627500	1220400	30700	178700	0.0	14671900	0	14671900	246093100
16	5537	24916500	1186500	29900	173800	0.0	14213100	0	14213100	260306200
17	5379	24205500	1152600	29000	168800	0.0	13754000	0	13754000	274060200
18	5221	23494500	1118800	28200	163900	0.0	13293800	0	13293800	287354000
19	5064	22788000	1085100	27300	158900	0.0	12834100	0	12834100	300188100
20	4906	22077000	1051300	26500	154000	0.0	12373000	0	12373000	312561100
21	4748	21366000	1017400	25600	149000	0.0	11910400	0	11910400	324471500
22	4591	20659500	983800	24800	144100	0.0	11448500	0	11448500	335920000
23	4433	19948500	949900	23900	139100	0.0	10984700	0	10984700	346904700
24	4275	19237500	916100	23100	134200	0.0	10519700	0	10519700	357424400
25	4118	18531000	882400	22200	129200	0.0	10055100	0	10055100	367479500
26	3960	17820000	848600	21400	124300	0.0	9588200	0	9588200	377067700
27	3802	17109000	814700	20500	119300	0.0	9120600	0	9120600	386188300
28	3645	16402500	781100	19700	114400	0.0	8652700	0	8652700	394841000
29	3487	15691500	747200	18800	109400	0.0	8182500	0	8182500	403023500
30	3329	14980500	713600	18000	104500	0.0	7711300	0	7711300	410734800
TOT	146001	657004500	31286100	787700	4582000		410734800	0	410734800	

LIFETIME AVERAGE INCREASE IN UNIT REVENUE REQUIREMENT

DOLLARS PER TON OF COAL BURNED	13.13	0.0	13.13
MILLS PER KILOWATT-HOUR	5.63	0.0	5.63
CENTS PER MILLION BTU HEAT INPUT	62.52	0.0	62.52
DOLLARS PER TON OF SULFUR REMOVED	521.44	0.0	521.44

REVENUE REQUIREMENT DISCOUNTED AT 11.6% TO INITIAL YEAR, DOLLARS 132942000 0 132942000

LEVELIZED INCREASE IN UNIT REVENUE REQUIREMENT EQUIVALENT TO DISCOUNTED REQUIREMENT OVER LIFE OF POWER UNIT

DOLLARS PER TON OF COAL BURNED	14.80	0.0	14.80
MILLS PER KILOWATT-HOUR	6.34	0.0	6.34
CENTS PER MILLION BTU HEAT INPUT	70.47	0.0	70.47
DOLLARS PER TON OF SULFUR REMOVED	587.98	0.0	587.98